A/D Converter Fundamentals

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Analog Devices

Class ID: CC11B
Renesas Electronics America Inc.
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Andrei Cozma: Design Manager

- Andrei holds a BS degree in Industrial Automation and Informatics and a PhD degree in Electronics and Telecommunications. He has been involved in the design and development of projects from different industry fields such as chemical parameters measurement, motor control, industrial automation, software defined radio and telecommunications.

- He has joined ADI in 2011 as ADI Romania Design Manager. His current job responsibilities include design of FPGA and MCU based systems as well as writing technical documentation for ADI reference designs.
Renesas Technology & Solution Portfolio
Agenda

- Introduction
- A/D Fundamentals
- A/D Converter Performance Parameters
- A/D Converters Architectures
- ADI Precision A/D Converters Products
- Advantages of Using External A/D Converters for Precision Applications
- Demo: Using an ADI Precision ADC with a Renesas MCU
- Summary
Introduction

- This lecture provides an introduction on the A/D converters types and technologies
- Talk about the parameters that characterize the performance of an A/D converter, about the features/tradeoffs of each A/D converter type and the advantages of using external converters for precision applications
- At the end of the lecture a demo is shown on how to use an ADI precision A/D converter Pmod with a Renesas MCU
- Take-aways:
  - Get familiar with the basics of analog to digital conversion and with the existing A/D converter types and technologies
  - Have an understanding of the main parameters that characterize an A/D converter's performance
  - Have an overview of ADI’s precision A/D converters and how they can be interfaced with Renesas MCUs
A/D Fundamentals
What is an Analog-Digital converter?

- Translates analog quantities, which are characteristic of most phenomena in the "real world," to digital language, used in information processing, computing, data transmission, and control systems.
- Produces a digital output corresponding to the value of the signal applied to its input relative to a reference voltage.
- Finite number of discrete values: $2^N$ resulting in quantization uncertainty.
- Changes continuous time signal into discrete time sampled representation.
- Sampling and quantization impose fundamental yet predictable limitations.
Sampling Process

- Sampling: representing a continuous time domain signal at discrete and uniform time intervals
- Prior to the actual analog-to-digital conversion, the analog signal usually passes through a lowpass / bandpass filter required to remove unwanted signals outside the bandwidth of interest and prevent aliasing
Nyquist Bandwidth & Aliasing

- Nyquist theory stipulates that the signal frequency $f_{\text{signal}}$ must be less than $\frac{1}{2} f_{\text{sampling}}$ to prevent aliasing.
- Aliasing: the difference component $f_{\text{sampling}} - f_{\text{signal}}$ appears within the signal bandwidth of interest.

$F_{\text{signal}} < \frac{1}{2} F_{\text{sampling}}$

$F_{\text{signal}} \geq \frac{1}{2} F_{\text{sampling}}$
Quantization Process

- Representing an analog signal having infinite resolution with a digital word having finite resolution
- Determines maximum achievable dynamic range
- Results in quantization error/noise
Quantization Noise

- The quantization step $q$ of a $N$ bit ADC for a input sine wave signal with peak value $A$ is
  - $q = A / 2^{N-1}$
- The RMS value of the quantization noise sawtooth is its peak value $q/2$ divided by $\sqrt{3}$
  - $\text{NOISE}_{\text{RMS}} = q / \sqrt{12}$
- The RMS value of a sine wave is its peak value $A$ divided by $\sqrt{2}$
  - $\text{SIGNAL}_{\text{RMS}} = A / \sqrt{2}$
- Signal to Noise Ratio for a $N$ bit A/D converter is
  - $\text{SNR} = \text{SIGNAL}_{\text{RMS}} / \text{NOISE}_{\text{RMS}} = 1.225 \times 2^N$
- Signal to Noise Ratio for a $N$ bit A/D converter expressed in dB is
  - $\text{SNR} = 20 \times \log(\text{SIGNAL}_{\text{RMS}} / \text{NOISE}_{\text{RMS}}) = 1.76 + 6.02N$ [dB]
Quantization Noise

- If the quantization noise is uncorrelated with the frequency of the AC input signal, the noise will be spread evenly over the Nyquist bandwidth of Fs/2.
- If, however the input signal is locked to a sub-multiple of the sampling frequency, the quantization noise will no longer appear uniform, but as harmonics of the fundamental frequency.
Analog Input Signal Definitions

- **UNIPOLAR SINGLE ENDED**
  - ![UNIPOLAR SINGLE ENDED Diagram](image)
- **BIPOLAR SINGLE ENDED**
  - ![BIPOLAR SINGLE ENDED Diagram](image)
- **PSEUDO DIFFERENTIAL**
  - ![PSEUDO DIFFERENTIAL Diagram](image)
- **UNIPOLAR DIFFERENTIAL**
  - ![UNIPOLAR DIFFERENTIAL Diagram](image)
- **BIPOLAR DIFFERENTIAL**
  - ![BIPOLAR DIFFERENTIAL Diagram](image)
Unipolar and Bipolar Converter Codes

**Unipolar**
- FS - 1LSB
- ALL "1"s
- 0

**Offset Binary**
- FS - 1LSB
- 1 AND ALL "0"s
- -FS

**2's Complement**
- FS - 1LSB
- ALL "1"s
- -(FS - 1LSB)
A/D Converter Offset and Gain Errors

- Analogous to offset and gain errors in amplifiers
- The transfer characteristic of an ADC may be expressed as a straight line given by:
  \[ D = K + GA \]
  where \( D \) is the digital code, \( A \) is the analog signal, and \( K \) and \( G \) are constants

- **Offset error**: the amount by which the actual value of \( K \) differs from its ideal value. In a unipolar converter, the ideal value of \( K \) is zero; in an offset bipolar converter it is \(-1 \) MSB

- **Gain Error**: the amount by which \( G \) differs from its ideal value; is generally expressed as the percentage difference between the two, although it may be defined as the gain error contribution (in mV or LSB) to the total error at full-scale
Offset and Gain Errors for Unipolar Ranges
Offset and Gain Errors for Bipolar Ranges

OFFSET ERROR

ACTUAL

ZERO ERROR

NO GAIN ERROR: ZERO ERROR = OFFSET ERROR

IDEAL

WITH GAIN ERROR: OFFSET ERROR = 0 ZERO ERROR RESULTS FROM GAIN ERROR

ACTUAL

ZERO ERROR

IDEAL
A/D Converter Performance Parameters
A/D Converter Performance Parameters

- **DC Performance**
  - Differential Non-Linearity (DNL)
  - Integral Non-Linearity (INL)

- **AC Performance**
  - Harmonic Distortion
  - Worst Harmonic
  - Total Harmonic Distortion (THD)
  - Total Harmonic Distortion Plus Noise (THD + N)
  - Signal-to-Noise-and-Distortion Ratio (SINAD, or S/N +D)
  - Effective Number of Bits (ENOB)
  - Signal-to-Noise Ratio (SNR)
  - Analog Bandwidth (Full-Power, Small-Signal)
  - Spurious Free Dynamic Range (SFDR)
  - Two-Tone Intermodulation Distortion
  - Noise Power Ratio (NPR) or Multitone Power Ratio (MPR)
Ideal DC Specifications

- Ideal ADC code transitions are exactly 1 LSB apart.
- For an N-bit ADC, there are $2^N$ codes. ($1 \text{ LSB} = \text{FS}/2^N$)
- For this 3-bit ADC, $1 \text{ LSB} = (1V/2^3 = 1/8)$
- Each “step” is centered on an eighth of full scale
A/D Converter Performance Parameters - DC

- **Differential Non-Linearity (DNL)**
  - The deviation of an actual code width from the ideal 1 LSB code
  - DNL error is measured in LSBs
  - Results in narrow or wider code widths than ideal
  - Results in additive noise/spurs beyond the effects of quantization
A/D Converter Performance Parameters - DC

- **DNL effects:**
  - *Missing Codes* — An ADC has missing codes if an infinitesimally small change in voltage causes a change in result of two codes, with the intermediate code never being set. A DNL of −1.0 LSB indicates the ADC has missing.
  - *Non-Monotonicity* — An ADC is *monotonic* if it continually increases conversion result with an increasing voltage (and vice versa). A non-monotonic ADC may give a lower conversion result for a higher input voltage, which may also mean that the same conversion may result from two separate voltage ranges.
A/D Converter Performance Parameters - DC

- **Integral Non-Linearity (INL)**
  - The deviation of an actual code transition point from its ideal position on a straight line drawn between the end points of the transfer function.
  - INL is calculated after offset and gain errors are removed
  - Results in additive harmonics and spurs
A/D Converter Performance Parameters - DC

**INL Measurement Methods**

- *End Point Method*: the deviation is measured from the straight line through the origin and the full-scale point (after gain adjustment)
- *Best Straight Line Method*: the best fit straight line is drawn through the transfer characteristic of the device using standard curve fitting techniques, and the maximum deviation is measured from this line
A/D Converter Performance Parameters - AC

- Dynamic Testing of A/D Converters
  - A Fast Fourier Transform (FFT) analyzer is used to measure dynamic performance

Diagram:

1. LOW PHASE JITTER SAMPLING CLOCK SOURCE
2. LOW PHASE JITTER SINEWAVE SOURCE
3. POWER SUPPLIES
4. BANDPASS FILTER
5. A/D CONVERTER ON EVALUATION BOARD
6. FFT ANALYZER
A/D Converter Performance Parameters - AC

- The Fast Fourier Transform converts a signal from time domain....

....to frequency domain
A/D Converter Performance Parameters - AC

- **SINAD (Signal to Noise and Distortion Ratio)**
  - The ratio of the rms signal amplitude to the mean value of the root-sum-squares (RSS) of all other spectral components, including harmonics, but excluding DC

- **ENOB (Effective Number of Bits)**
  - $ENOB = \frac{SINAD - 1.76\,dB}{6.02}$

- **SNR (Signal to Noise Ratio)**
  - The ratio of the rms signal amplitude to the mean value of the root-sum-squares (RSS) of all other spectral components, excluding the first five harmonics and DC
A/D Converter Performance Parameters - AC

- **SFDR, THD and SNR**

  - **SFDR** = The difference between the rms power of the fundamental and the largest spurious signal in a given bandwidth.

  - **THD** = The ratio of the rms sum of the first six harmonics to the amplitude of the fundamental.

  - **SNR** = The ratio of the rms value of the fundamental to the rms sum of all noise components in the Nyquist bandwidth (excluding harmonics).
A/D Converter Architectures
Successive Approximation ADC

- The most popular architecture for data-acquisition applications
- Basic SAR architecture
Successive Approximation ADC

- How does it work?
  - Rising/Falling edge of convert start pulse resets logic
  - Falling/Rising edge begins conversion process
  - Bit comparisons made on each clock edge
  - Conversion time equals number of comparisons (resolution) times clock period
  - The accuracy of conversion depends on the DAC linearity and comparator noise

**EXAMPLE: ANALOG INPUT = 6.428V, REFERENCE = 10.000V**
Successive Approximation ADC

- **Features**
  - Resolutions: 8 to 18 bits
  - Sampling rate: up to 3 MSPS

- **Advantages**
  - Low Power (12-bit/1.5 MSPS ADC: 1.7 mW)
  - Small die area and low cost
  - No pipeline delay

- **Tradeoffs**
  - Lower sampling rates

- **Typical applications**
  - Instrumentation
  - Industrial control
  - Data acquisition
SIGMA-DELTA ADC

- Low cost, high resolution (up to 24-bits)
- Can be implemented on what is primarily a digital process
- Key concepts are simple, but math is complex
  - Oversampling
  - Quantization Noise Shaping
  - Digital Filtering
  - Decimation
SIGMA-DELTA ADC

- Oversampling, Digital Filtering, Noise Shaping, And Decimation
SIGMA-DELTA ADC

- First order SIGMA-DELTA ADC
SIGMA-DELTA ADC

- **Features**
  - Resolution: up to 24 bits
  - Sampling rate: up to 2MHz for 12 to 16 bits, up to 192 kSPS for higher resolutions

- **Advantages**
  - High resolutions and accuracy (24-bits)
  - Excellent DNL and INL performance
  - Noise shaping capability

- **Tradeoffs**
  - Limited input bandwidth
  - Slower sampling rates

- **Typical applications**
  - Precision data acquisition and measurement
  - Medical instrumentation
  - Audio
Flash ADC

- 2N-1 comparators form the digitizer array, where N is the ADC resolution
- Analog input is applied to one side of the comparator array, a 1 lsb reference ladder voltage is applied to the other inputs.
- The comparator array is clocked simultaneously and decides in parallel.
- Output logic converts from thermometer code to binary
Flash ADC

- **Features**
  - Resolution: up to 10 bits
  - Sampling rate: up to 1.5 GSPS

- **Advantages**
  - Fastest conversion times
  - Low data latency

- **Tradeoffs**
  - Higher power consumption
  - High capacitive input is difficult to drive

- **Typical Applications**
  - Video digitization
  - High-speed data acquisition
Pipelined ADC

- Conversion divided into discrete stages thus causing pipeline delay
  - 1st ADC is 3 bit Flash
  - 2nd Stage ADC is 4 bit Flash
  - Total resolution is 6 bits (one bit used for error correction)
Pipelined ADC

- **Features**
  - Resolution: up to 16 bits
  - Sampling rate: up to 100 MSPS+

- **Advantages**
  - Higher resolutions at high-speeds
  - Digitize wideband inputs

- **Tradeoffs**
  - Higher power dissipation
  - Larger die size

- **Typical Applications**
  - Communications
  - Medical imaging
  - Radar
A/D Converter Selection

- General way how these application segments and the associated typical architectures relate to ADC resolution (vertical axis) and sampling rate (horizontal axis)
- Even though the various architectures have specifications with a good deal of overlap, the applications themselves are key to choosing the specific architecture required
ADI Precision ADCs Products
ADI Precision ADCs Product Range

- Single CHANNEL, 8-bit to 12-bit resolution ADCs
- Multichannel, SPI and I2C, 8-bit to 12-bit resolution ADCs
- Parallel, 10 bits to 12 bits
- True bipolar-input, 12-bit to 18-bit resolution ADCs
- Simultaneous sampling ADCs
- 24-Bit, wide bandwidth analog-to-digital converters
- Σ-Δ ADCs
- Precision resolution, 14 bits to 18 bits
- High speed SAR ADCs
- Programmable, 14-bit to 18-bit resolution, bipolar ADCs
- ADCs for automotive applications
ADI Precision ADCs Products Features

- Extended product range suited for a large number of applications with different accuracy, data throughput and power requirements

<table>
<thead>
<tr>
<th>ADI Precision ADC Family</th>
<th>Features</th>
</tr>
</thead>
</table>
| **Single Channel, 8-Bit to 12-Bit Resolution ADCs** | • Flexible throughputs range from 200 kSPS to 3 MSPS  
• Temperature range: −40°C up to +125°C  
• Low power dissipation: 3.6 mW at 3 MSPS  
• Flexible power/throughput management  
• SAR architecture zero pipeline delay |
| **Multichannel, SPI and I2C, 8-Bit to 12-Bit Resolution ADCs** | • Flexible throughputs range from 2kSPS to 1 MSPS across a range of channel counts - 2, 4, 8, 16  
• Power dissipation ranges from 0.3 mW for the I2C range to up to a maximum of 6 mW for the SPI range |
| **True Bipolar-Input, 12-Bit to 18-Bit Resolution ADCs** | • Throughput rates of up to 1 MSPS for the 13-bit parts and 670 kSPS for the 18-bit parts  
• Higher input impedances and higher bandwidths  
• Input signals from ±2.5V to ±10V  
• Power dissipation range from 10mW to 215mW |
| **Σ-Δ ADCs** | • Programmable data rates from 4.7 Hz to 4.8 kHz  
• Ultralow noise (8.5 nV rms)  
• Up to 22.5 bits noise-free resolution  
• Integrated PGA and clock  
• Simultaneous 50 Hz/60 Hz rejection  
• Temperature specified up to +105°C |
ADI Precision ADCs Applications

- Single Channel ADCs
  - High speed data acquisition
  - Instrumentation and control systems
  - Optical module power detection
  - Battery-powered systems

- Multichannel ADCs
  - Channel monitoring
  - Battery and temperature measurements
  - Medical instruments
  - Voltage and current monitoring
  - Infotainment

- Σ-Δ ADCs
  - Weigh scales
  - Distributed control systems
  - Programmable logic controllers
ADI Precision ADCs Pmods

- ADI Precision ADCs Pmod boards are compatible with Renesas MCU Development Boards
- What are the Pmods?
  - Small I/O interface boards that offer an ideal way to extend the capabilities of development boards
  - Communicate with system boards using 6 or 12-pin connectors
  - Four main categories
    1. Input / Output
    2. Sensor / Actuators
    3. Data acquisition and conversion
    4. Connectors

- Complete list at: www.digilentinc.com/AnalogDevices
# ADI Precision ADCs Pmods

<table>
<thead>
<tr>
<th><strong>PmodAD1</strong> - Two 12-bit A/D inputs</th>
<th><strong>PmodAD2</strong> - 4 channel 12-bit A/D converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Devices AD7476</td>
<td>Analog Devices AD7991</td>
</tr>
<tr>
<td><img src="image1.png" alt="PmodAD1" /></td>
<td><img src="image2.png" alt="PmodAD2" /></td>
</tr>
<tr>
<td>Sampling rate: 1MSPS</td>
<td>Sampling rate: 1MSPS</td>
</tr>
<tr>
<td>Resolution: 12 bit</td>
<td>Resolution: 12 bit</td>
</tr>
<tr>
<td>No. of Channels: 2</td>
<td>No. of Channels: 4</td>
</tr>
<tr>
<td>Interface: SPI</td>
<td>Interface: I2C</td>
</tr>
<tr>
<td>ADC type: SAR</td>
<td>ADC type: SAR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PmodAD4</strong> - 1 channel 16-bit A/D converter</th>
<th><strong>PmodAD5</strong> - 4 channel 24-bit A/D converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Devices AD7980</td>
<td>Analog Devices AD7193</td>
</tr>
<tr>
<td><img src="image3.png" alt="PmodAD4" /></td>
<td><img src="image4.png" alt="PmodAD5" /></td>
</tr>
<tr>
<td>Sampling rate: 1MSPS</td>
<td>Sampling rate: 4.8kSPS</td>
</tr>
<tr>
<td>Resolution: 16 bit</td>
<td>Resolution: 24 bit</td>
</tr>
<tr>
<td>No. of Channels: 1</td>
<td>No. of Channels: 4</td>
</tr>
<tr>
<td>Interface: SPI</td>
<td>Interface: SPI</td>
</tr>
<tr>
<td>ADC type: PULSAR®</td>
<td>ADC type: Σ-Δ</td>
</tr>
</tbody>
</table>

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ADI Precision ADCs Pmods

**PmodAD6** - 1 channel 24-bit A/D converter
Analog Devices AD7091R

Sampling rate: 1MSPS
Resolution: 12 bit
No. of Channels: 1
Interface: SPI
ADC type: SAR
Ultralow power

- Renesas MCU development boards with Pmod connectors
  - RL78/G13 RDK
  - RL78/G14 RDK
  - RX63N RDK
ADI Precision ADCs Pmods Reference Projects

- ADI Precision ADCs Pmod reference projects for Renesas MCUs – wiki.analog.com
- The Wiki is a collaborative space allowing the sharing of knowledge and content between ADI engineers and the design engineering community
ADI Precision ADCs Pmods Reference Projects

- Wiki project contents
  - Hardware setup guide
  - Software setup guide
  - Reference project overview
  - Software project tutorial
  - Project source code to download

**AD7900 - NO-CIS DRIVER FOR RENESAS MICROCONTROLLER PLATFORMS**

**SUPPORTED DEVICES**
- AD7900

**OVERVIEW**
The AD7900 is a 16-bit, successive-approximation, analog-to-digital converter (ADC) that operates from a single 4.75 to 5 V power supply. It can be powered by an external 1.8 V to 3.6 V supply and has no external reference pin. It features an analog input with a full-scale range of 0 to 1.3 V. The AD7900 is capable of handling high-speed data rates and has a 24-bit resolution. The device features a differential input and an output buffer, making it suitable for high-precision applications.

**Applications**
- Battery-powered equipment
- Communications
- ATE
- Data acquisition
- Medical instruments

**TABLE OF CONTENTS**
- AD7900 - 16-bit Driver for Renesas Microcontroller Platforms
  - Evaluation Boards
  - Driver
  - Driver Description
  - Hardware Setup
  - Quick Start Guide

**RENESEAL RL78G13 QUICK START GUIDE**

This section contains a description of the steps required to run the AD7900 demonstration project on a Renesas RL78G13 platform.

**Required Hardware**
- Renesas Demo Kit RL78G13 (Renesas)
- Pmod04

**Required Software**
- LR Embedded Workshop for Renesas RL78 Kitstart
- Applied for RL78G13

**Hardware Setup**
A Pmod04 has to be connected to the Pin011 connector.

**Software Setup**
With the Applied for RL78G13 kit the following peripherals have to be configured:
ADI Precision ADCs Pmods Projects Support

- Technical support for ADI Precision ADCs Pmod reference projects for Renesas MCUs—ez.analog.com
- **EngineerZone** is a technical support forum from ADI
  - It allows you direct access to ADI technical support engineers
  - Use it also to connect with other developers who face similar design challenges
Advantages of Using External A/D converters for Precision Applications
MCU Integrated ADCs

- Many of today’s MCUs contain integrated ADCs
- MCU ADCs provide a very convenient way of digitizing analog signals without the need of external hardware
- The MCU ADC is connected to the MCU’s internal bus providing an easy and fast way to access the conversion data

<table>
<thead>
<tr>
<th>Renesas MCU</th>
<th>A/D Converter Characteristics</th>
</tr>
</thead>
</table>
| RL78/G14      | Resolution: 10 bit  
No. of channels: up to 20  
Conversion time: 2.1 μs |
| RL78/G1A      | Resolution: 12 bit  
No. of channels: up to 28  
Conversion time: 3.375 μs |
| RL78/1A       | Resolution: 8/10 bit  
No. of channels: up to 11  
Conversion time: 2.125 μs |
| RX62N         | Resolution: 10 bit / 12bit  
No. of channels: 8 x 10 bit / 8 x 12 bit  
Conversion time: 1 μs |
| RX63N         | Resolution: 10 bit / 12bit  
No. of channels: up to 8 x 10 bit / up to 21 x 12 bit  
Conversion time: 1 μs |
External ADCs vs MCU Integrated ADCs

- MCU integrated ADCs have reasonable performance characteristics and are suited for applications that do not have tight precision requirements
- External ADCs are designed having in mind specific uses cases and thus are optimized to give the best performance for certain types of applications
- Multichannel external ADCs are capable of higher throughput rates than multichannel MCU integrated ADCs
- External ADCs can provide better DC and AC performance than MCU integrated ADCs

### MCU A/D Converter Performance

<table>
<thead>
<tr>
<th>RX63N 10 bit, 8 channel, ADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <em>Throughput</em>: 1MSPS for all channels</td>
</tr>
<tr>
<td>• <em>Offset error</em>: ±3.0 LSB max</td>
</tr>
<tr>
<td>• <em>DNL</em>: ±1.0 LSB max</td>
</tr>
<tr>
<td>• <em>INL</em>: ±3.0 LSB max</td>
</tr>
</tbody>
</table>

### External A/D Converter Performance

<table>
<thead>
<tr>
<th>AD7918, 10 bit, 8 channel, 1MSPS ADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <em>Throughput</em>: 1MSPS for each channel</td>
</tr>
<tr>
<td>• <em>Offset error</em>: ±2.0 LSB max</td>
</tr>
<tr>
<td>• <em>DNL</em>: ±0.5 LSB max</td>
</tr>
<tr>
<td>• <em>INL</em>: ±0.5 LSB max</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RX63N 12 bit, 14 channel, 1MSPS ADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <em>Throughput</em>: 1MSPS for all channels</td>
</tr>
<tr>
<td>• <em>Offset error</em>: ±7.5 LSB max</td>
</tr>
<tr>
<td>• <em>DNL</em>: ±4.0 LSB max</td>
</tr>
<tr>
<td>• <em>INL</em>: ±4.0 LSB max</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AD7490, 12 bit, 16 channel, 1MSPS ADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <em>Throughput</em>: 1MSPS for each channel</td>
</tr>
<tr>
<td>• <em>Offset error</em>: ±8.0 LSB max</td>
</tr>
<tr>
<td>• <em>DNL</em>: -0.95 / +1.5 LSB max</td>
</tr>
<tr>
<td>• <em>INL</em>: ±1.0 LSB max</td>
</tr>
</tbody>
</table>
Demo: Using an ADI Precision ADC with a Renesas MCU
ADI Precision ADC with a Renesas MCU Demo

- The demo shows how to read data from a PmodAD6 (AD7091R) using a Renesas RX63N RDK and provides a comparison between the SNR of the data captured using the PmodAD6 and the SNR of the MCU’s internal 12 bit, 1MSPS ADC for the same input signal.

- The AD7091R is a 12-bit, ultra low power, SAR ADC. It operates from a single 2.7 V to 5.25 V power supply and is capable of achieving a sampling rate of 1 MSPS. Features an on-chip conversion clock, accurate reference and high-speed SPI interface.

- A Digilent Analog Discovery portable analog circuit design kit is used to generate the input signals for the two ADCs.

- **Digilent Analog Discovery** features:
  - Dual Channel Oscilloscope
  - Function Generators
  - 16 Channel Logic Analyzer
  - Dual Power Supplies
  - USB Powered
Hardware setup

- Renesas RX63N RDK
- PmodAD6 (AD7091R ADC)
- Digilent Analog Discovery Kit
System architecture
Experimental results - RX63N internal ADC

- Test signal: 1KHz sine wave
- Sampling rate: 500 KSPS
- RX63N internal ADC read data waveform and FFT

- SNR: 41.97dB
Experimental results - PmodAD6

- Test signal: 1KHz sine wave
- Sampling rate: 500 KSPS
- PmodAD6 read data waveform and FFT

SNR: 43.65dB
Summary and Q/A
Summary

The lecture covered:

- Basics of analog to digital conversion
- Existing A/D converter types and technologies
- Main parameters that characterize an A/D converter's performance
- ADI’s precision A/D converters product range and how they can be interfaced with Renesas MCUs

Take-aways:

- Get familiar with the basics of analog to digital conversion and with the existing A/D converter types and technologies
- Have an understanding of the main parameters that characterize an A/D converter's performance
- Have an overview of ADI’s precision A/D converters and how they can be interfaced with Renesas MCUs
More Info

- ADI Precision ADCs Product Brochure

- ADI Technical Documentation

- ADI Microcontroller No-OS Reference Projects

- ADI Microcontroller No-OS Forum

- ADI Pmods
  - http://digilentinc.com/Products/Catalog.cfm?NavPath=2,1040&Cat=20

- Digilent Analog Discovery
  - http://digilentinc.com/Products/Detail.cfm?NavPath=2,1040,1043&Prod=ANALOG-DISCOVERY
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