Introduction to noise in ADC systems
TI Precision Labs – ADCs

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ADC noise topics

- Introduction to noise in data acquisition systems
- ADC noise types
- Measuring and specifying ADC noise
- Defining system noise performance for low-speed delta-sigma ADCs
- Understanding effective noise bandwidth
- How gain affects ADC noise and dynamic range
- Do you need an amplifier for your high-resolution ADC?
- How reference noise affects ADC noise performance
- Reference noise reduction methods
Noise example

High-Resolution Image

Noisy Image

Photo by Patrick Thomas via https://unsplash.com/photos/Oaqk7qqNh_c
### WHAT is noise & WHY is it important?

<table>
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<th><strong>WHAT?</strong></th>
<th><strong>WHY?</strong></th>
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| Any unwanted signal that distorts or interferes with the desired signal, causing it to deviate from its original value. | - Noise limits the smallest signal you can resolve  
- Noise is a system-level design consideration  
- Noise affects overall system accuracy |
WHERE does noise come from?

- Sensor Noise
- Layout Noise
- Clock Jitter
- Power Supply Noise
- Reference Noise
- Thermal Noise & Quantization Noise
- 1/f Noise & BB Noise
The goal of this Precision Labs series

![Diagram of an amplifier and ADC circuit]

- **Amp**
- **ADC**
- **VREF**
- **VDD**
- **AVDD**
- **REF**
- **VIN**
- **VOUT**
- **Output Code**

Input: **V_IN**
Output: **V_OUT**
Reference: **VREF**
Power Supplies: **VDD**, **AVDD**, **REF**
More bits ≠ higher resolution

To increase precision, consider the overall **system’s** noise contribution, not just the ADC’s resolution.

*same noise shown at different resolutions*
**Precision versus accuracy**

**Precision** = ability of the ADC to provide repeatable results ("resolution")

**Accuracy** = how closely the ADC’s digital output corresponds to the analog input signal

- **High precision, high accuracy**
- **High precision, low accuracy**
- **Low precision, low accuracy**
- **Low precision, high accuracy**
Vector addition for uncorrelated errors

\[ V_{nT} = \sqrt{V_{n1}^2 + V_{n2}^2} \]

\[ V_{n1} = 1 \text{mV} \]

\[ V_{n2} = 5 \text{mV} \]

\[ V_{nT} = \sqrt{1^2 + 5^2} \]

\[ V_{nT} = 5.1 \text{mV}_{\text{RMS}} \]

Only 2% increase in noise!
Thanks for your time! Please try the quiz.
Quiz: Introduction to noise in data acquisition systems

1. (T/F) Changing from a 20 bit converter to a 24 bit converter may NOT actually increase your systems resolution if the noise is too large.
   
   a. True.
   b. False.
Quiz: Introduction to noise in data acquisition systems

2. An input signal of 2V is applied to three different ADC systems. Which system has good precision but poor accuracy?

a. System A  
b. System B  
c. System C

- **System A**
  - Input: 2.00V
  - Output: 2.00, 2.01, 1.99, 2.00, 2.02, 1.98

- **System B**
  - Input: 2.00V
  - Output: 2.10, 2.11, 2.09, 2.10, 2.12, 2.08

- **System C**
  - Input: 2.00V
  - Output: 2.20, 2.11, 1.89, 2.03, 2.12, 1.93
Quiz: Introduction to noise in data acquisition systems

3. For the circuit below the amplifier and ADC noise will add together. What is the total noise.

a. 3.00µV  
   b. 3.16µV  
   c. 3.22µV  
   d. 4.00µV

\[ E_{n_{\text{Total}}} = \sqrt{(3\mu V)^2 + (1\mu V)^2} = 3.16\mu V \]
Thanks for your time!