Methodology for Minimizing Mismatches in Time-Interleaved ADCs

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Goal

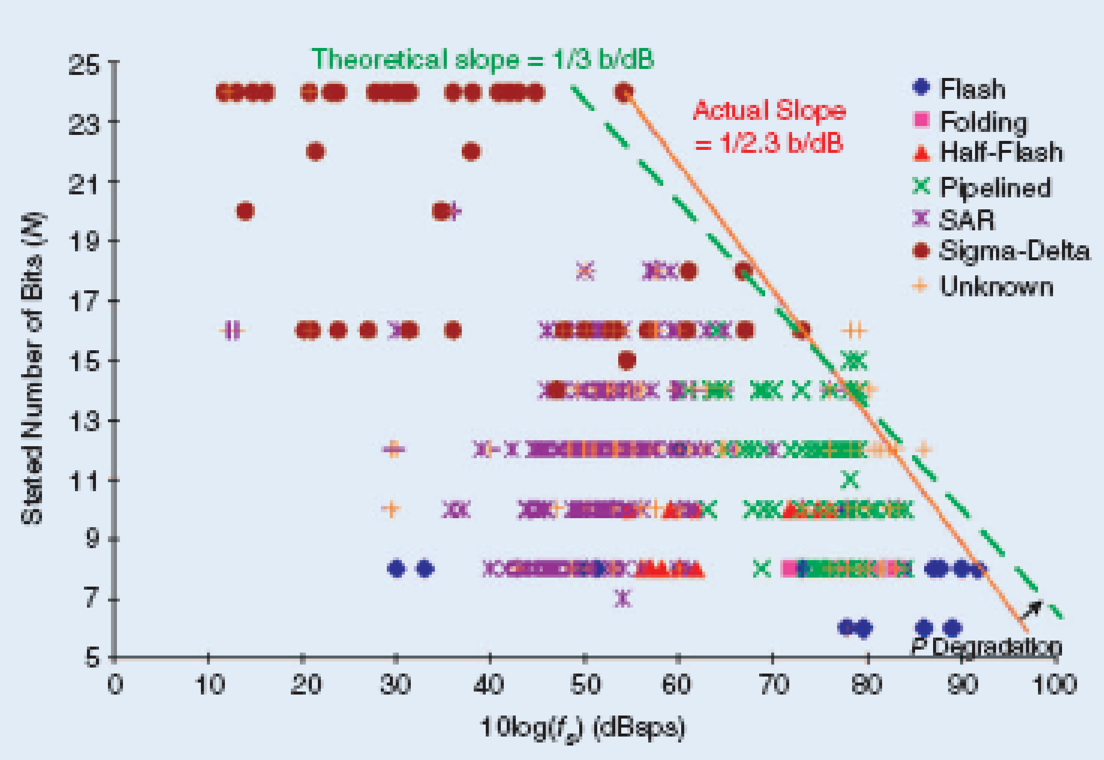
- Answer the following questions:
  - ⇒ How does a time-interleaved ADC (TIADC) work and why do we need it?
  - ⇒ What are the major problems associated with TIADCs?
  - ⇒ How can we mitigate these problems by using additional ADCs?

Introduction

- Important ADC Specifications
  - ⇒ Sampling Rate (MS/s)
  - ⇒ Resolution (e.g. signal-to-noise-and-distortion ratio (SINAD), spurious-free-dynamic range (SFDR))
  - ⇒ Power Consumption (e.g. pJ/S)

Introduction

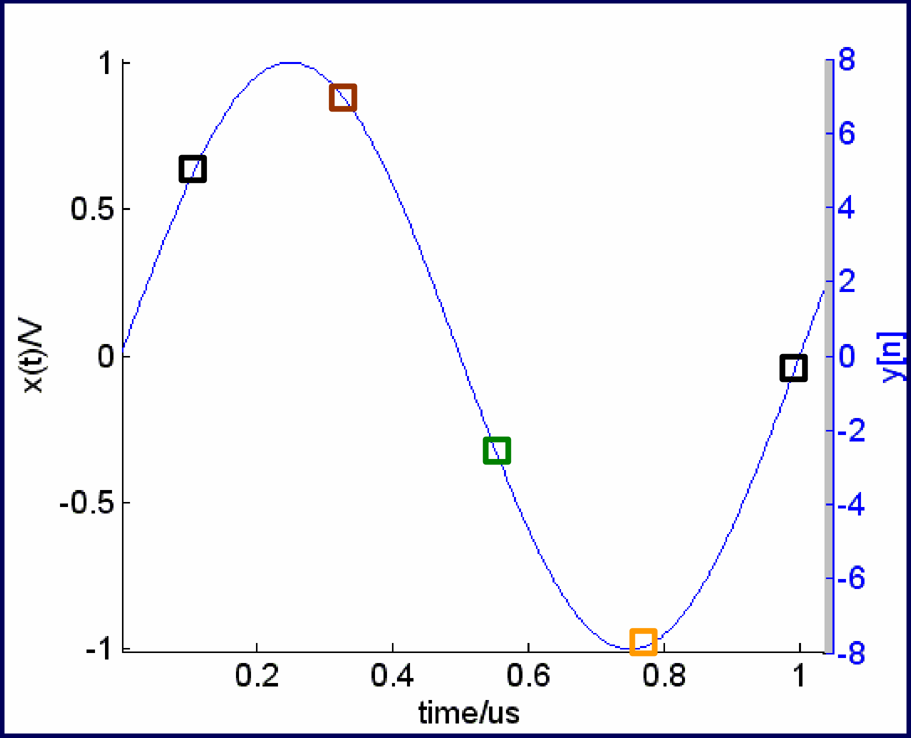
- Resolution vs. Sampling Rate

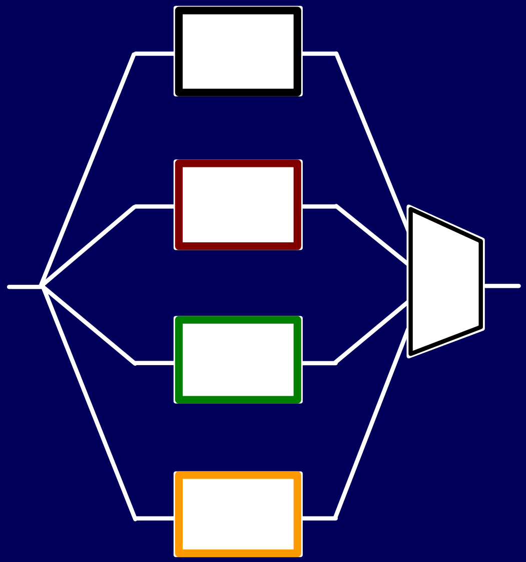


[1] Bin Le. *Analog-to-Digital Converters, IEEE Signal Processing Magazine, 2005, vol. 22, pp. 69-77*

Introduction

- Time-Interleaved ADC

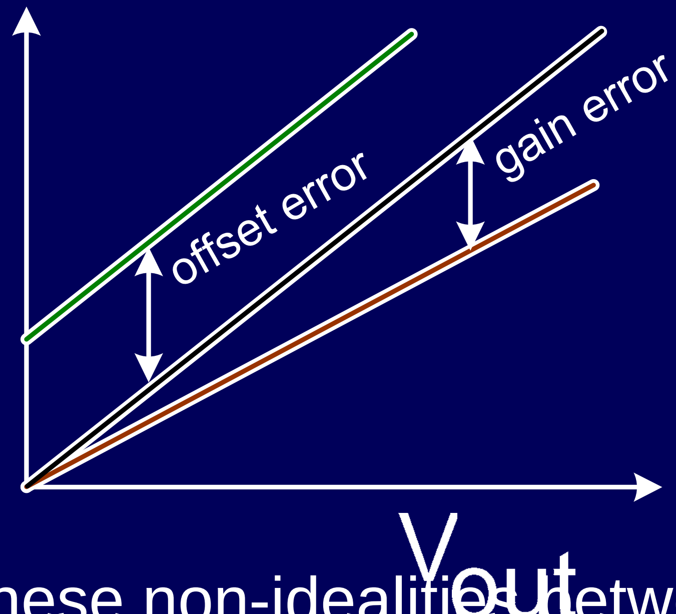




⇒ Increased sampling rate & maximum input bandwidth

Impact of Mismatch

- Definition



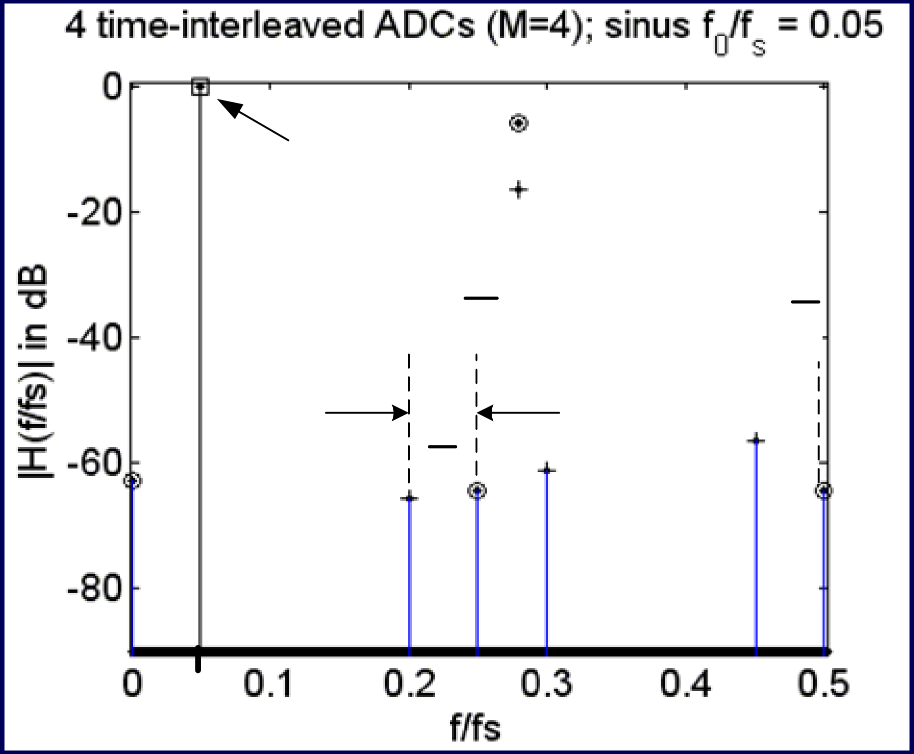
⇒ ADCs have individual transfer characteristics (gain, offset, DNL, INL)

⇒ ADCs show different response time regarding sample aquisition

⇒ These non-idealities between the different ADCs introduce undesired frequency components in the output spectrum

Impact of Mismatch

- Spurious Tones in the Spectrum



⇒ Location of offset tones: $f_{offset} = k\, f_s / M$

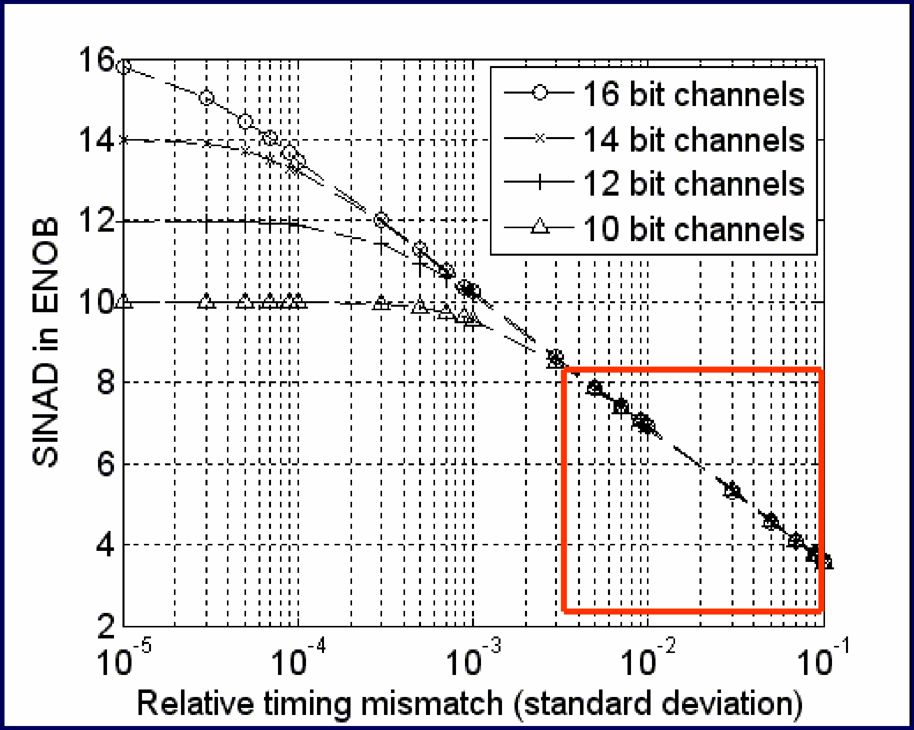
⇒ Location of gain and timing mismatch tones $f_{gain,tim} = k\, f_s / M \pm f_0$

⇒ Decreased SINAD & SFDR performance

offset sp
gain & ti
spurs
signal

Impact of Mismatch

- SINAD Degradation

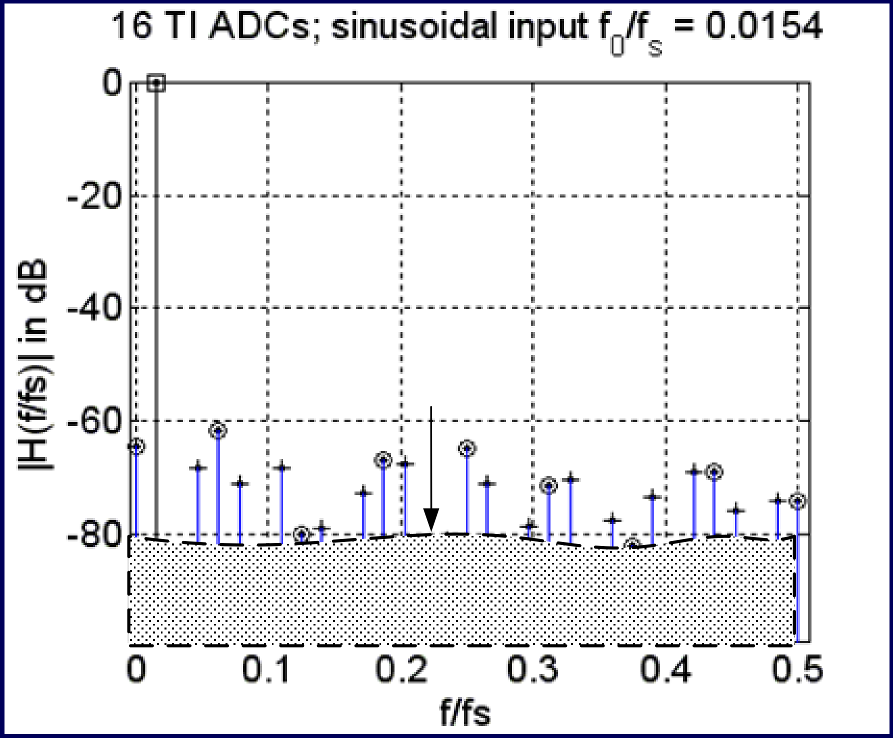


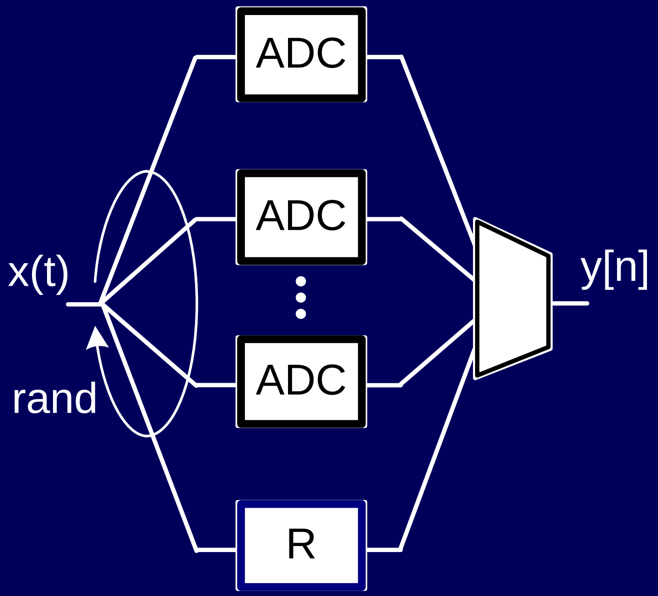
⇒ Poor SINAD for high timing mismatch (~0.4 % std. dev.)

⇒ Increasing channel resolution has no influence on system performance

Selection Ordering Methods

- Randomisation [1]



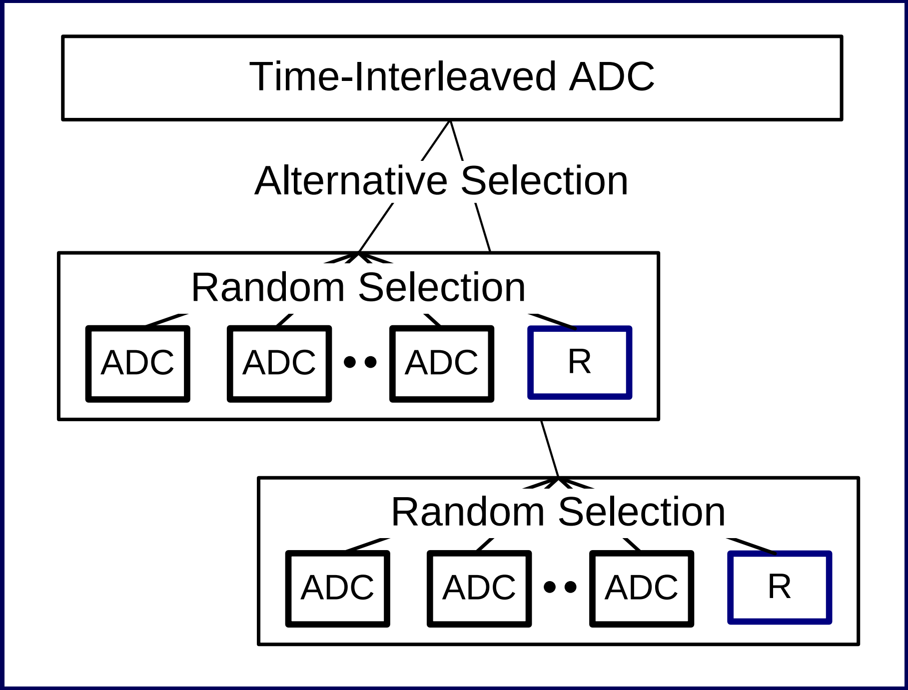


⇒ SFDR improved by using additional ADCs for randomisation

[1] H. Jin et al. *Time-Interleaved A/D Converter with Channel Randomization, IEEE Transactions on Instrumentation and Measurement, vol. 54, 1997, pp. 425-428*

Selection Ordering Methods

- Grouping & Randomisation [2]



⇒ Creates spurious tones in the upper Nyquist band

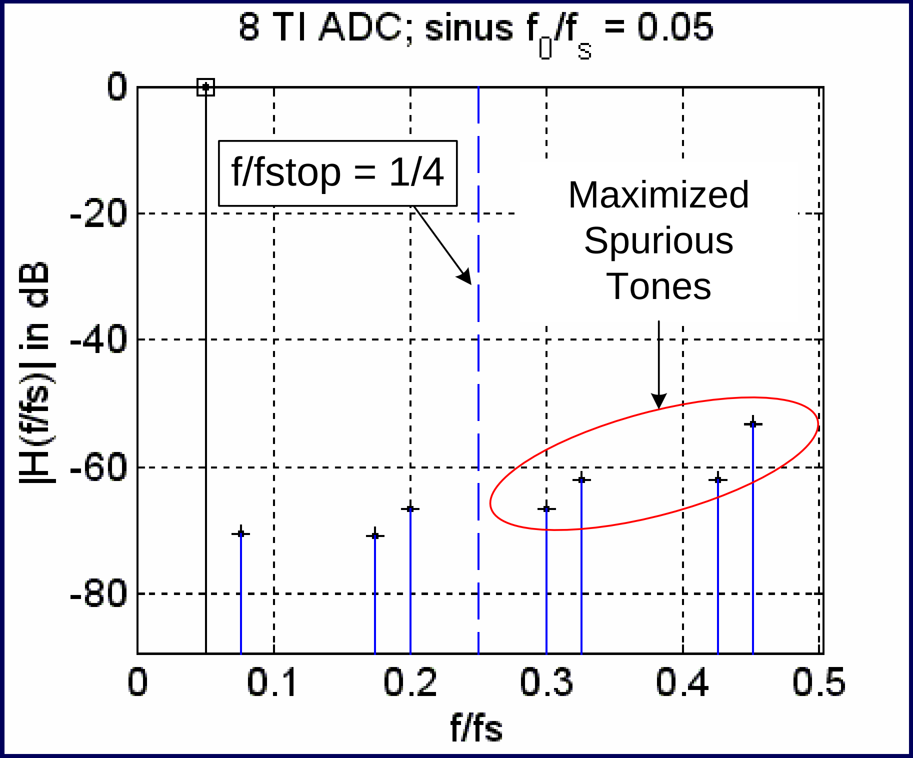
⇒ Tones are removed by means of low-pass filtering (fstop = fs/4)

⇒ In band SINAD & SFDR are improved at the cost of bandwidth

[2] Christian Vogel. *A Novel Randomization Method for Time-Interleaved ADCs, Proc. of the IEEE Instrumentation and Technology Conference, vol. 1, 2005, pp. 150-155*

Selection Ordering Methods

- Spectral Shaping [3]



⇒ Linear rotation scheme employing (*no random*.)

⇒ Tones are removed by means of low-pass filtering (fstop = fs/4)

⇒ In band SINAD & SFDR are improved at the cost of bandwidth

[3] Christian Vogel. *Spectral Shaping of Timing Mismatches in Time-Interleaved ADCs, IEEE International Symposium on Circuits and Systems, vol. 2, 2005, pp. 1394-1397*

Proposed Method

- Timing Mismatch Ordering & Grouping

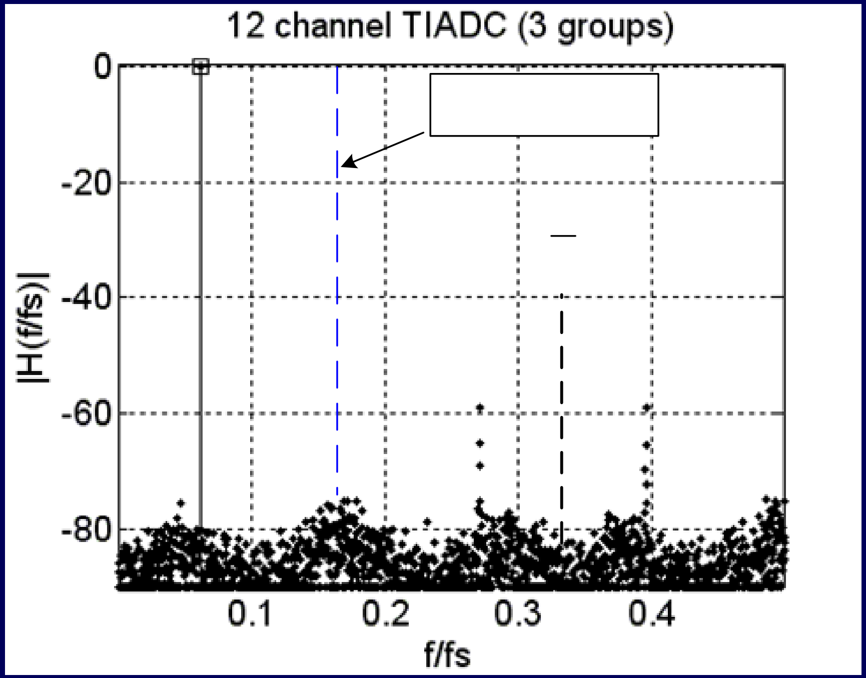
  ⇒ More out-of-band spurious tones are created by utilising a larger number of groups

  ⇒ ADCs are assigned to the groups so the targeted out-of-band spurious tones are maximized

  ⇒ Noise related to other mismatch sources is removed in this process as well but not as efficient as the targeted mismatch effect

Proposed Method

- Example: 12 ADCs assigned to 3 groups



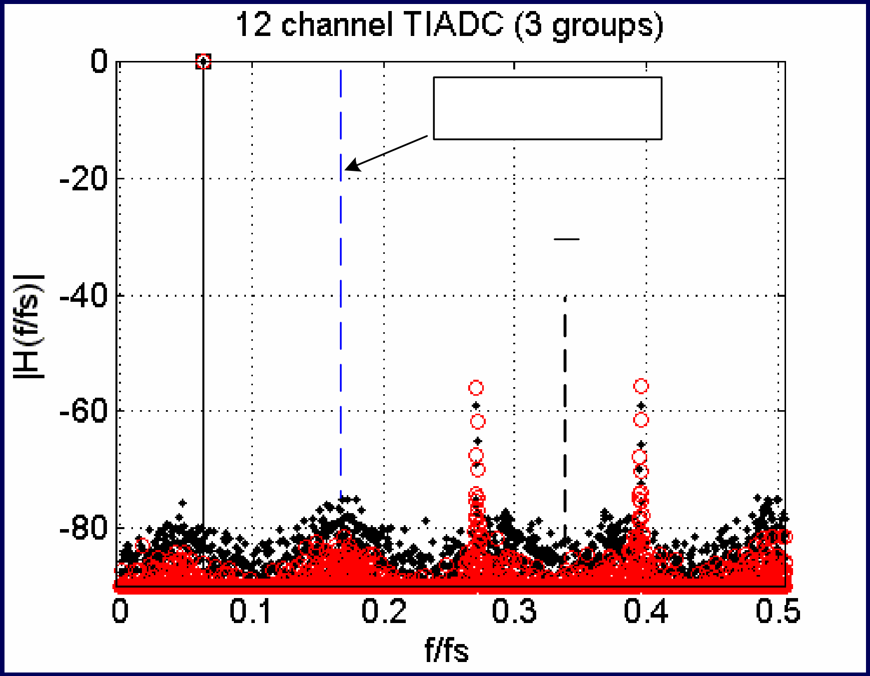
⇒ Unoptimized Case

SINAD = *9.2 ENOB*

SFDR = *76.8 dB*

Proposed Method

- Example: 12 ADCs assigned to 3 groups



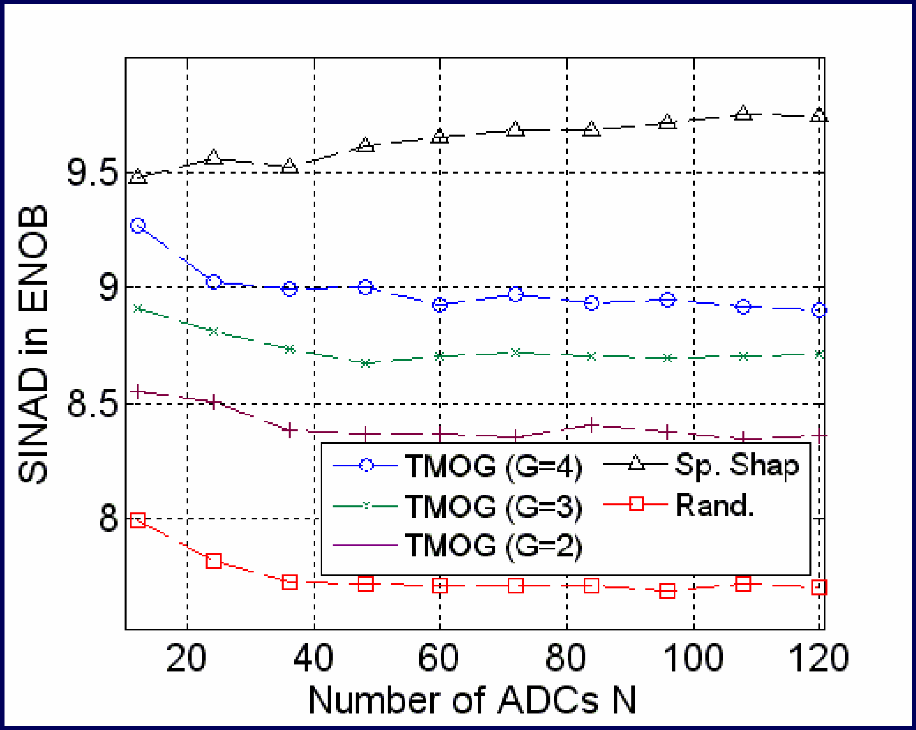
⇒ Unoptimized Case
SINAD = *9.2 ENOB*
SFDR = *76.8 dB*

⇒ Optimized Case
SINAD = *10.2 ENOB*
SFDR = *81.7 dB*

f/fstop = 1/6

Simulation Results

- Comparison of Methods (SINAD)



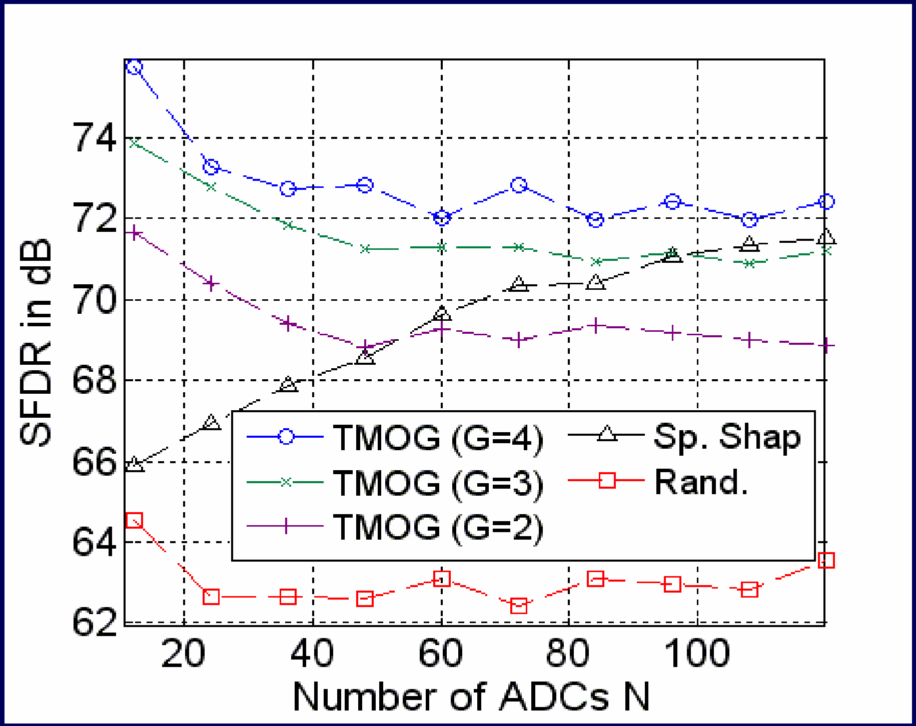
⇒ 1% Timing Mismatch 0.1% Gain & Offset Gaussian distributed (Std. Deviation)

⇒ Ideal filter (stop band frequency f/fstop = 1/8)

⇒ Increasing group number results in improved SINAD

Simulation Results

- Comparison of Methods (SFDR)



⇒ An increasing group number provides improving SFDR

⇒ *Superior SFDR performance*

Conclusion

- ⇒ Channel mismatch significantly degrades overall performance
- ⇒ Controlling the selection order of the individual ADCs allows us to shape the spectrum
- ⇒ Filtering the shaped spectrum achieves better performance than pure oversampling and filtering
- ⇒ Proposed technique shows good SINAD & SFDR performance for a wide range of ADC numbers

Thank you for your attention

ctvr

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