Caractérisation de l'instabilité des oscillateurs : étude des performances logicielles et matérielles d'un banc de mesure à base d'électronique numérique reconfigurable

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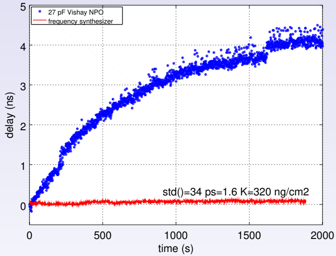
Why Digital Instrumentation?

Comparison between digital and analog implementation:

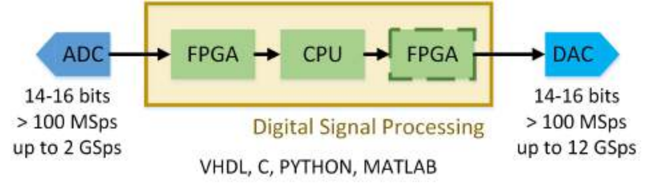
Sampling Time Generator for stroboscopic measurement.



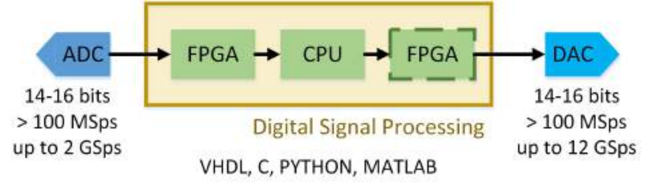
Ground Penetrating Radar (GPR)

- Analog components highly dependent on environmental factors, drift, aging and tuning.
- Digital implementations - Software Defined Radio (SDR) techniques.

General Purpose Digital Instrument Structure



General Purpose Digital Instrument Structure



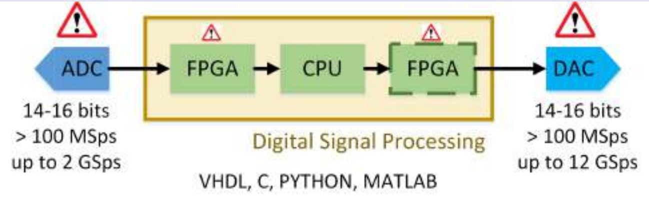
- **Stability:** Once the code or configuration algorithm (FPGA) is working it will work in the same way over time.
- **Reconfigurability:** Modifications during development can be performed only by changing the algorithm (CPU or FPGA configuration). Good for testing new approaches and techniques.
- **Flexibility:** Reproducible systems just by changing parameters (gains, coefficients, data resolution, etc.).

Replacing Analog with Digital Introduces Some New Challenges

- Discrete Time: Limited Observation Bandwidth
- Aliasing
- Quantization
- Sample Representation: Integer, Fixed Point, Floating Point

That could be taken as opportunities for the development of new approaches as: *Stroboscopic Measurement*

Understanding Hardware Limitations: Characterization of Front-End Hardware

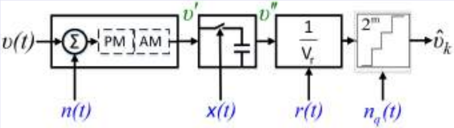


Available noise information of the components at frequency offsets far from the carrier.

Model for ADC Phase and Amplitude Noise Characterization

Extract and discriminate the different noise sources.

- Predict effects of ADC noise on the digital system performance.
- Characterization for time and frequency metrology applications.



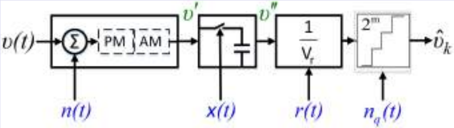
$n(t)$: Addtive Noise of Input Stage.
$x(t)$: Aperture Jitter.
$r(t)$: Voltage Reference Noise.
$n_q(t)$: Quantization Noise $\rightarrow$ high resolution ADCs

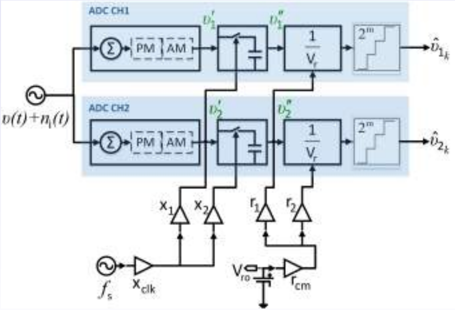
$$S_{\varphi,s}(f) = \frac{1}{V_0^2} S_{n_\varphi,s}(f) + 4\pi^2 {\nu_0}^2 S_{x,s}(f) \qquad S_{\alpha,s}(f) = \frac{1}{V_0^2} S_{n_\alpha,s}(f) + S_{r,s}(f)$$

Model for ADC Phase and Amplitude Noise Characterization

Extract and discriminate the different noise sources.

- Predict effects of ADC noise on the digital system performance.
- Characterization for time and frequency metrology applications.
- Differential applications ⇒ Common noise rejection.

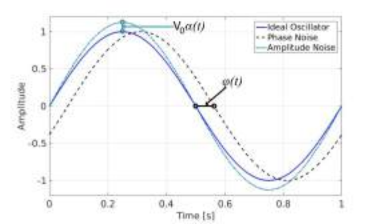


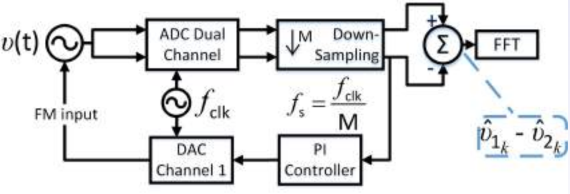


Method for the Extraction of ADCs Noise Components

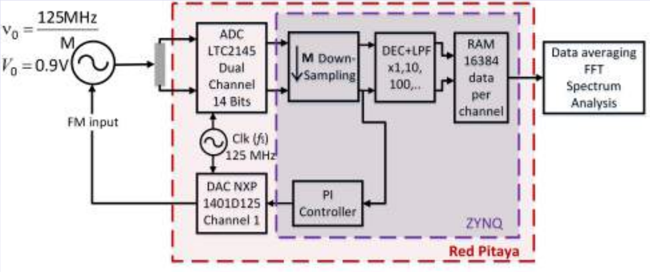
$$S_{\varphi,s}(f) = \frac{1}{V_0^2} S_{n_\varphi,s}(f) + 4\pi^2 {\nu_0}^2 S_{x,s}(f)$$

$$S_{\alpha,s}(f) = \frac{1}{V_0^2} S_{n_\alpha,s}(f) + S_{r,s}(f)$$





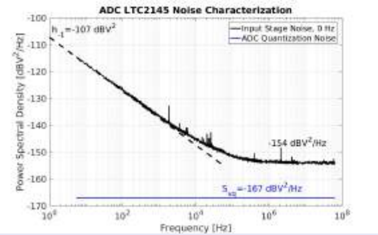
Implementation of the Method Proposed

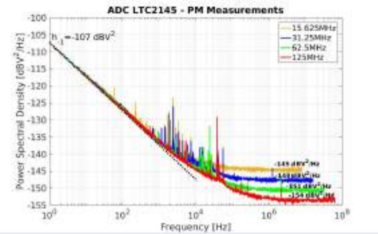


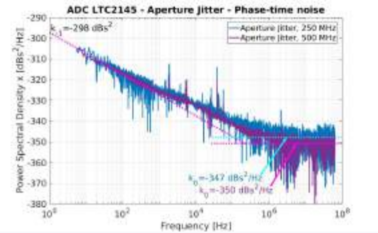
Red Pitaya Platform:

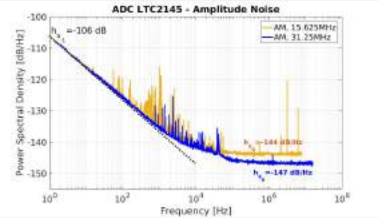
- 14-bit dual channel ADC, 125 MSps
- 14-bit dual channel DAC, 125 MSps
- System On Chip (SoC) = ARM processor + FPGA

ADC Noise Characterization

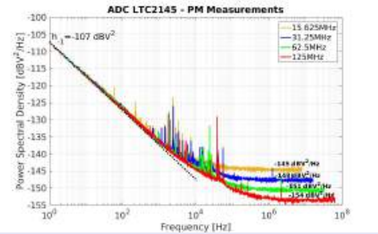


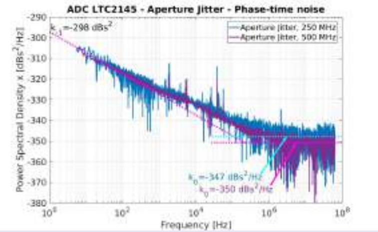






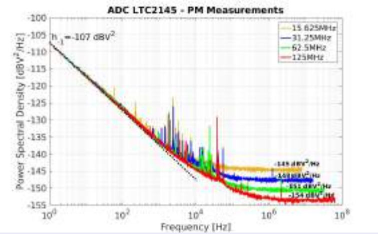
ADC Noise Characterization

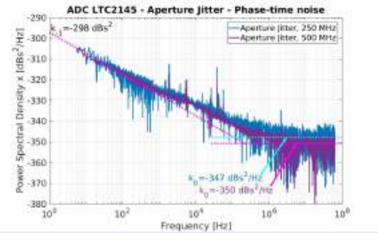




Parameter	**Square Root Value ADC LTC2145 Common Mode**
$\mathrm{h_0B} = \frac{\mathsf{b_{s_0}} f_s V_0^2}{2}$	$\sqrt{\mathrm{h_0B}} = 159\ \mu V_{rms}$
$\mathrm{h_{-1}} = \mathsf{b_{s_{-1}}} V_0^2$	$\sqrt{\mathrm{h_{-1}}} = 4.5\ \mu V$
$\mathsf{J}^2 = \mathsf{k_0} \frac{f_s}{2}$	$\mathsf{J} = 25\ \mathrm{fs_{rms}}$
$\mathsf{k_{-1}}$	$\sqrt{\mathsf{k_{-1}}} = 1.3\ \mathrm{fs}$

Comparing ADC LTC2145 Phase Noise Results





Parameter Phase Noise	ADC LTC2145	Generic Mixer	Amplifier OPA354A
$\sqrt{h_0}$	$10\ nV/\sqrt{Hz}$ B = 250 MHz	$3\ nV/\sqrt{Hz}$ 5 - 10 MHz	$6.5\ nV/\sqrt{Hz}$ B = 250 MHz
$\sqrt{h_{-1}}$	$4.5\ \mu V$	$0.1\ \mu$V	$1.9\ \mu$V

For comparison with amplifiers and mixers.

Discussion and Conclusions

- The model and the method can be reproduced for the characterization of any ADC architecture.
- Working with high resolution ADCs reduces the effect of the quantization noise. At high speed and high input amplitude a better performance is achieved.
- The ADC noise is dominated by the noise of the input stage that is equally distributed between amplitude and phase noise.
- Even if this component could limit low noise measurements, the characterization brings key information for noise rejection techniques.

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(Available at: `http://jmfriedt.free.fr/rsi_ADC_Characterization.pdf`)

Current and Future Work

- Study of other critical blocks: DAC and PLL.
- Noise characterization of other platforms with different architectures and features.
- This project is part of GoDigital group that is currently working on:
  - Arithmetic analysis and scheduling of digital processing and
  - On implementation of applications for time/frequency metrology based on digital instrumentation.

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