Poster ID: 520

Hardware Demonstration of Low-Rate and High-Dynamic Range ADC

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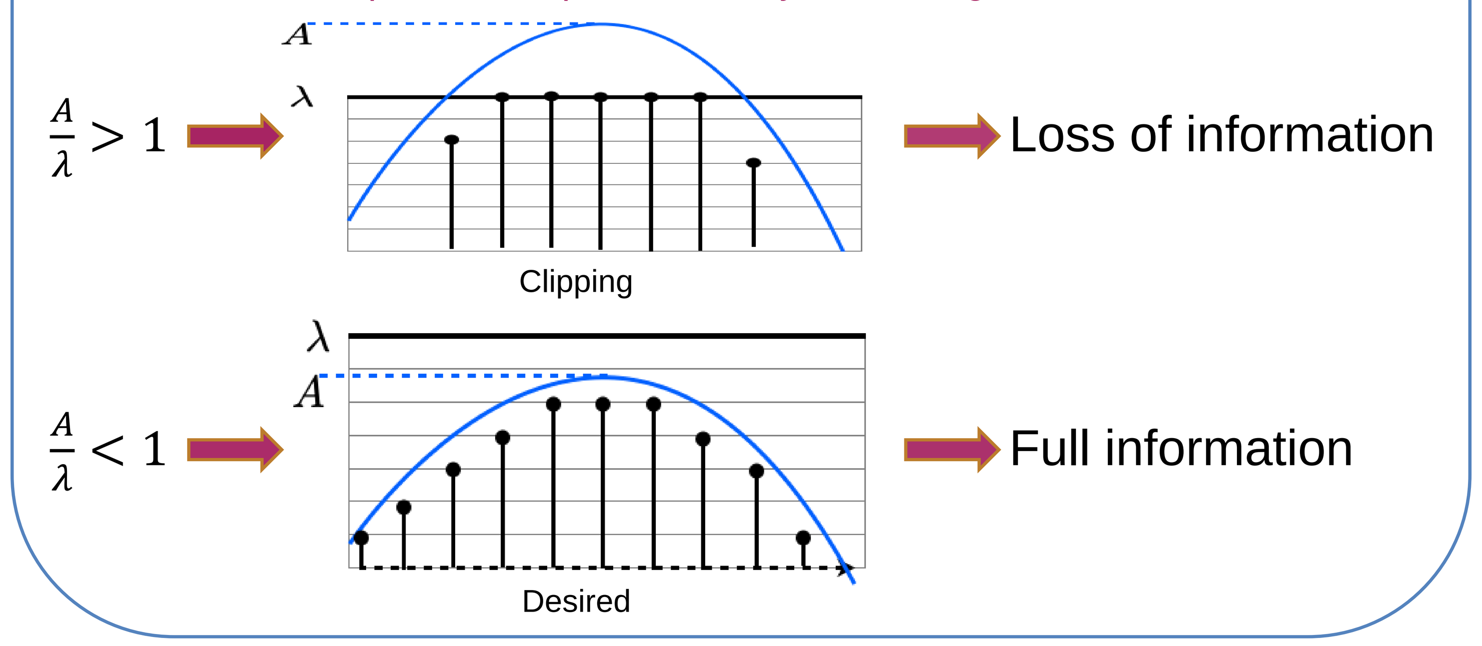
Motivation and Contributions

- Sampling and quantization are critical tasks of an ADC
- At high sampling rates ADCs are expensive and power consuming
- Large amplitude of the input compared to the dynamic range of an ADC results in clipped/saturated signal during quantization
- To address clipping, modulo (wrapping) operation is applied on the signal to restrict the dynamic range
- Existing reconstruction algorithms operate at a much higher rate compared to the rate without a modulo operation
- We propose a new B^2R^2, Beyond Bandwidth Residual Recovery, algorithm so that unwrapping can be performed robustly at a low sampling rate
- We propose a dedicated hardware prototype that can handle high frequency and high amplitude input signal

Dynamic Range of ADC

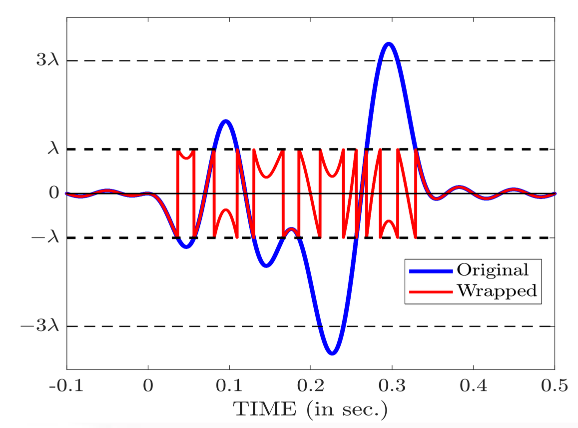
- The ratio of maximum amplitude of an input and the dynamic range of an ADC is crucial in signal processing

A: max amplitude of input λ: dynamic range of ADC



Modulo Sampling and Reconstruction

- To avoid clipping, an unlimited sampling approach (based on Higher Order Difference-HOD) is proposed by Bhandari et al. IEEE TSP 2020 and Chebyshev Polynomial Filtering (CPF) approach is proposed by Ordentlich et al. IEEE SPL 2019
- To restrict the amplitude of the input, $f(t)$, within the dynamic range, λ, the above approaches uses a modulo operation, $M_\lambda(\cdot)$
- **HOD**: The reconstruction algorithm, R, operates at 17 times the Nyquist and is not robust to noise
- **CPF:** The reconstruction algorithm, R, is not robust to noise
- We demonstrate an alternative algorithm called B^2R^2 that operates at 3 times the Nyquist rate in the presence of noise



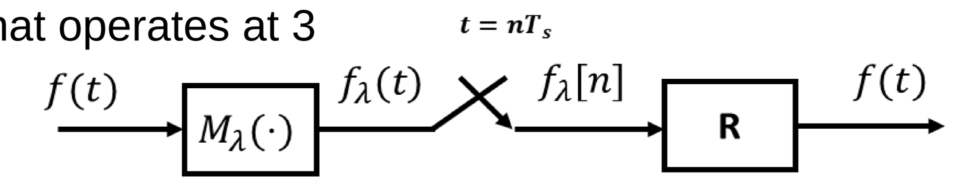


Fig: Sampling and reconstruction of BL signal by using a modulo operation

B^2R^2 Algorithm

Define: $f_\lambda[n] = f[n] + z[n]$ $f_\lambda[n]$: Modulo samples, $f[n]$: True samples, $z[n]$: Residual samples

- **Aim:** Estimation of $z[n]$ using the two properties of given finite energy bandlimited (BL) signal

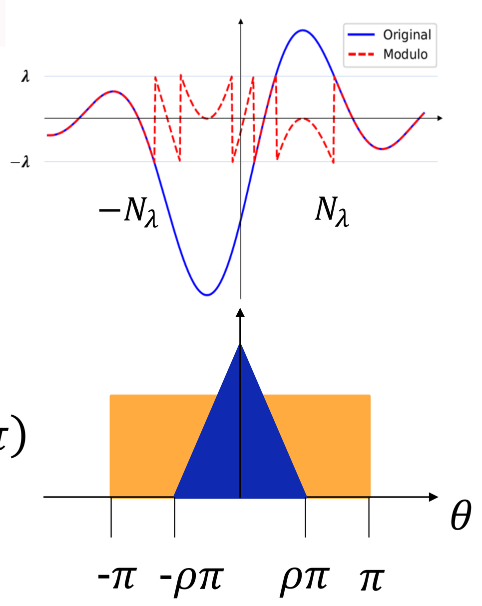
Property 1: Time-Domain separation

$$\exists N_\lambda \in \mathbb{N}: z[n] = 0, \forall |n| > N_\lambda$$

Property 2: Fourier-Domain separation

$$\mathcal{F}_r(z[n]) = \mathcal{F}_r(f_\lambda[n]);\ r = (\rho\pi, \pi) \cup (-\pi, -\rho\pi)$$

$\mathcal{F}_r$: Partial DTFT over a range r



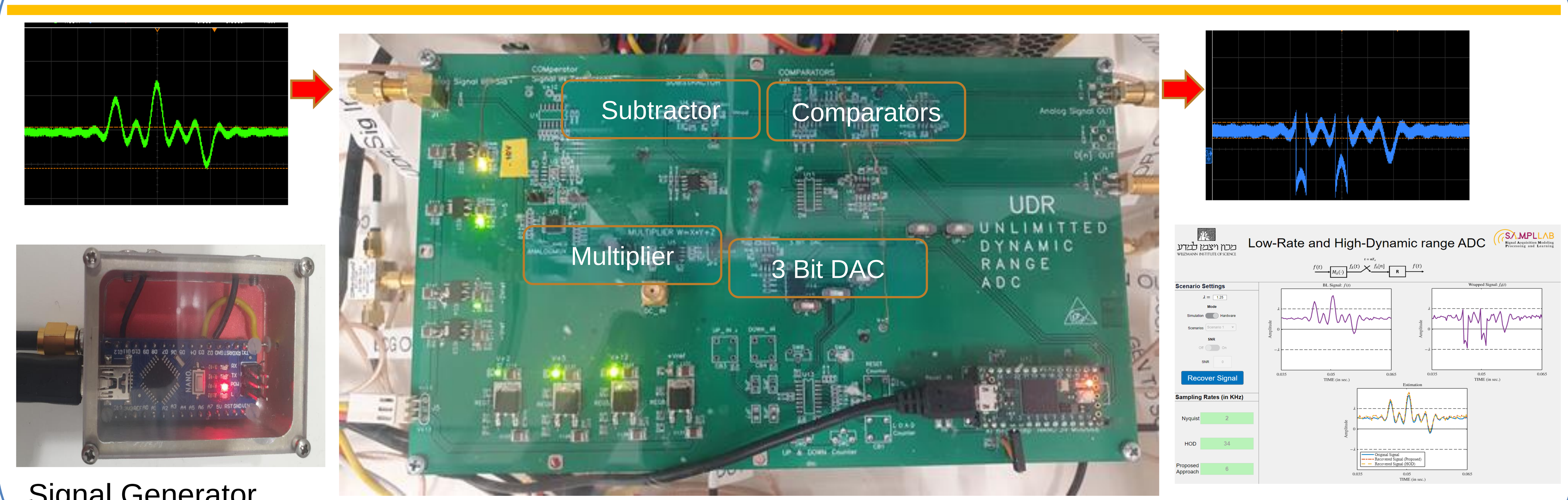
Formulating Convex Optimization Problem:

$$\min_{z} \|\mathcal{F}_\rho(f_\lambda - z)\|_2^2$$
$$s.t\ z[n] = 0, |n| > N_\lambda$$

Projected Gradient Decent Algorithm

Estimated $z[n]$

Hardware

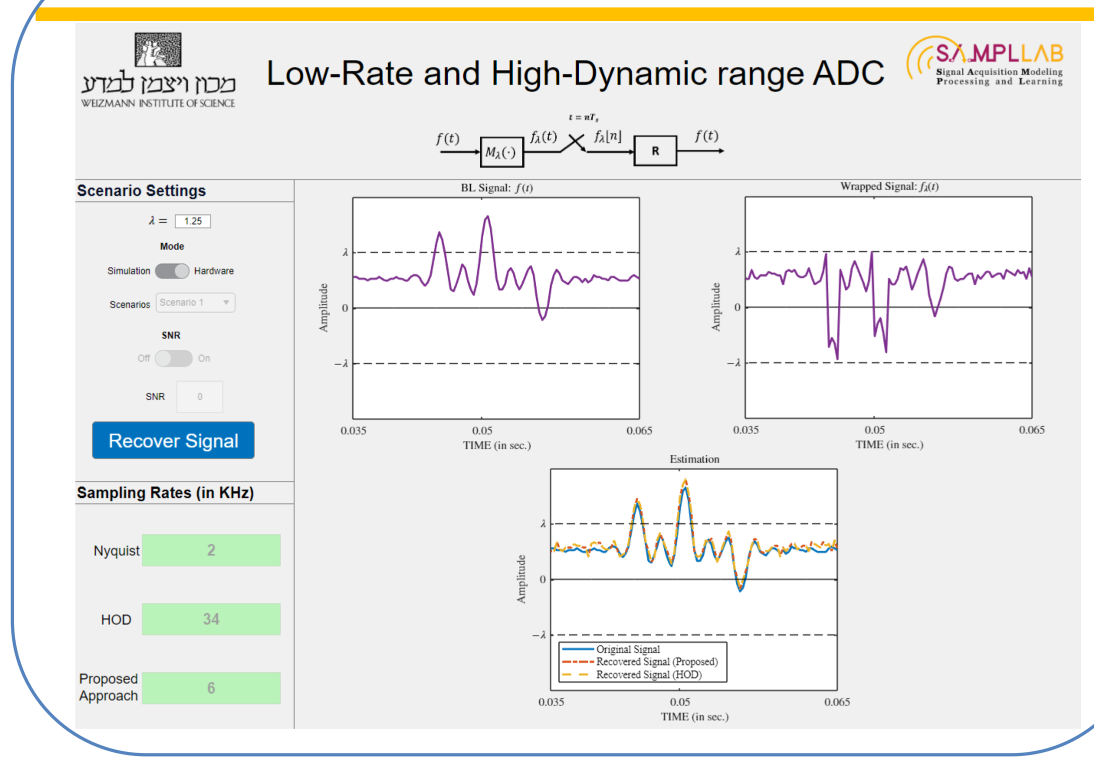


Signal Generator (Microcontroller) Modulo Board Graphical User Interface

Modulo Board Details

- Board characteristics:
  - Has the ability to handle input amplitude that is 8 times the dynamic range
  - Provides high frequency support
- The folding is done with:
  (a) Comparators – in order to identify the input signal level,
  (b) 3 Bit DAC, (c) Multiplier and
  (d) Subtractor in order to adjust the analog signal prior to sample it via a standard ADC

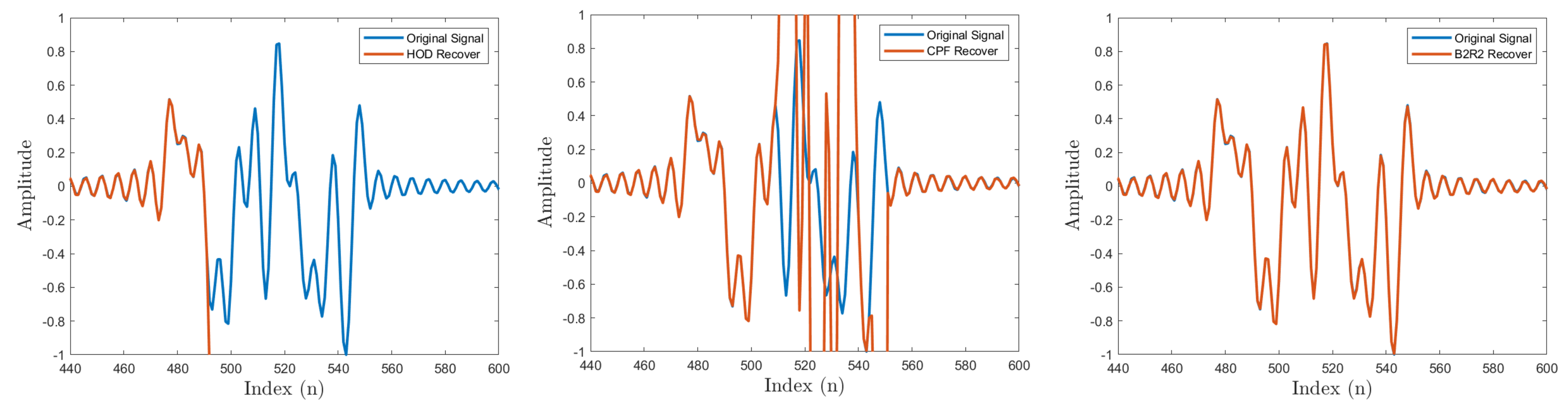
User Interface



Results

Simulation Results

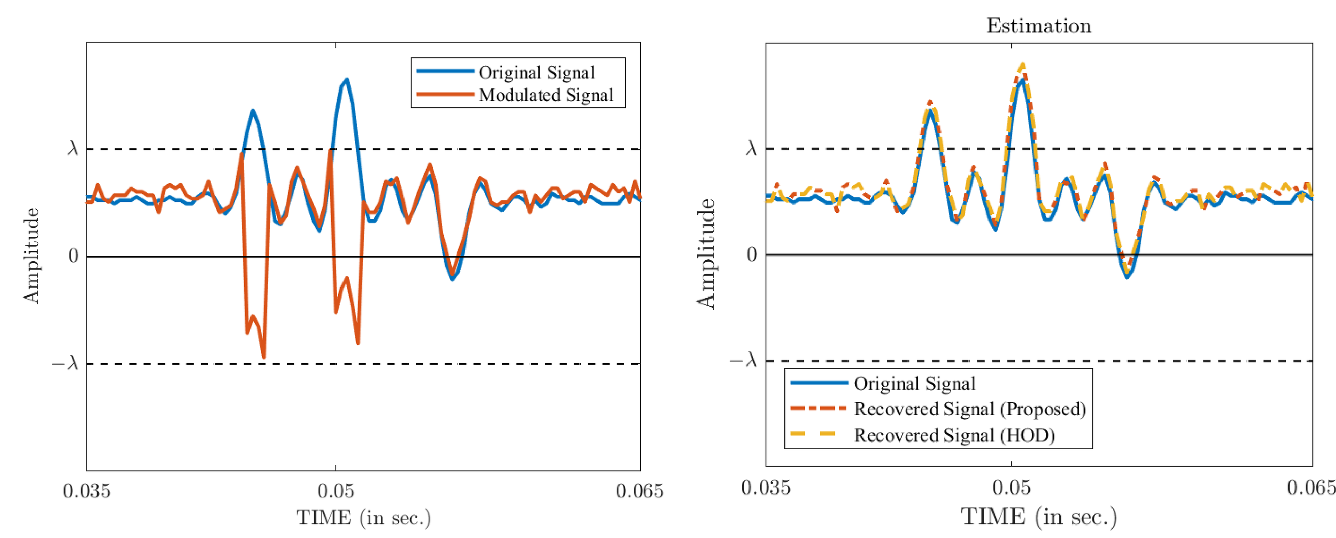
B^2R^2 is robust to noise



Nyquist: 2KHz HOD, CPF, B^2R^2: 6KHz SNR: 20 dB

	HOD	CPF	B^2R^2
Low Sampling Rate	✗	✓	✓
Robust to Noise	✗	✗	✓

Hardware Results



Sampling rates: Nyquist 2KHz, HOD: 34KHz; Proposed approach: 6KHz

- The Bandwidth of $f(t)$ is equal to 2KHz
- The proposed algorithm is able to reconstruct the original BL signal at 3 times the Nyquist rate
- Our modulo hardware addresses the dynamic range issue of a given BL signal with modulo operator using B^2R^2 algorithm
- Our modulo board can be used in real-life applications, such as radars, sensors, etc.