PERFORMANCE TRADE-OFFS AND DESIGN LIMITATIONS OF ANALOG-TO-INFORMATION CONVERTER FRONT-ENDS

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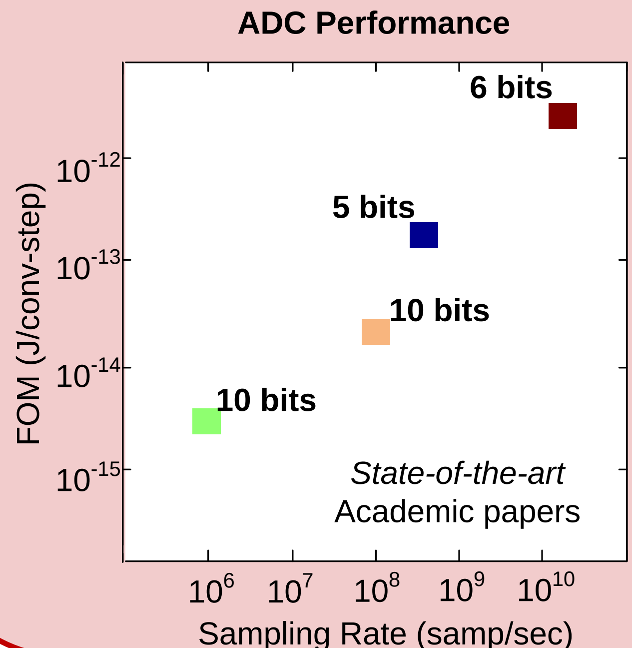
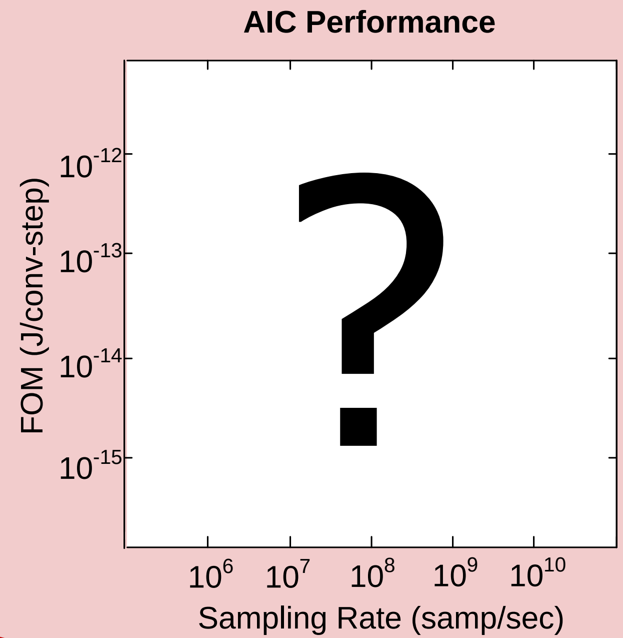
MOTIVATION

- High-speed sampling resolution limiter:
  - Jitter (sampling uncertainty)
  - Aperture (circuit bandwidth)

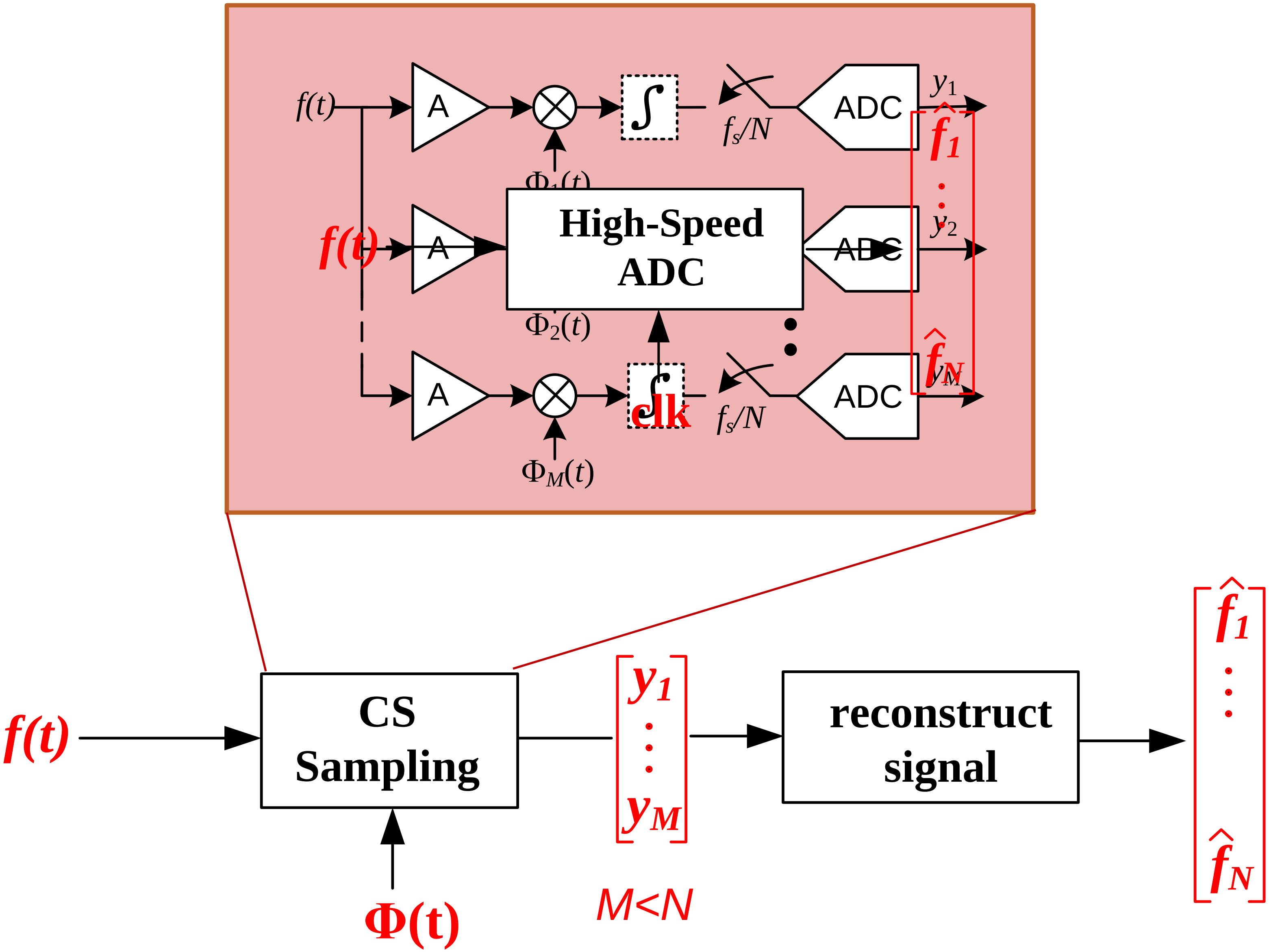
- High-speed ADCs:
  - High Power
  - Limited Resolution



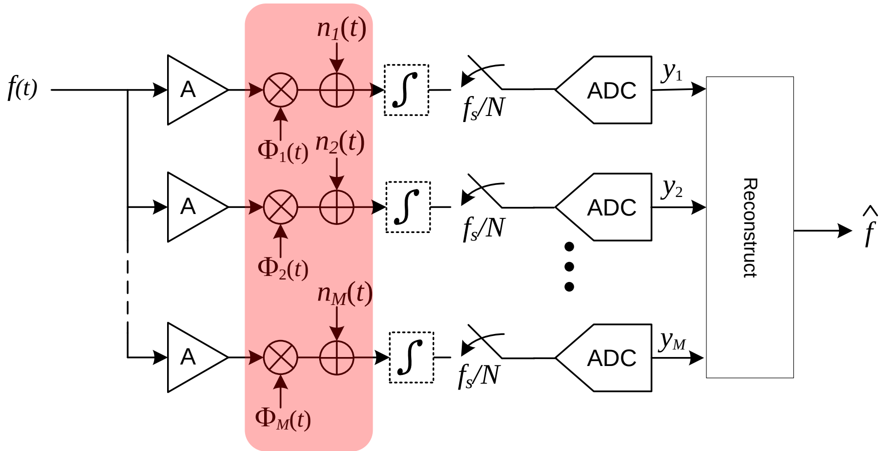
- Analog-to-Information Converters (AIC) :
  - Relax the frequency requirements of ADC

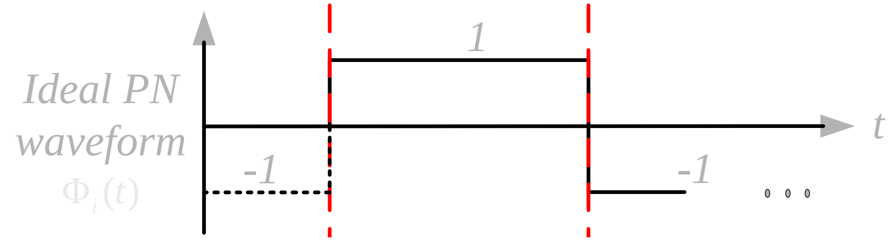


AIC: Compressed Sensing



Mixer Clocking Jitter Model

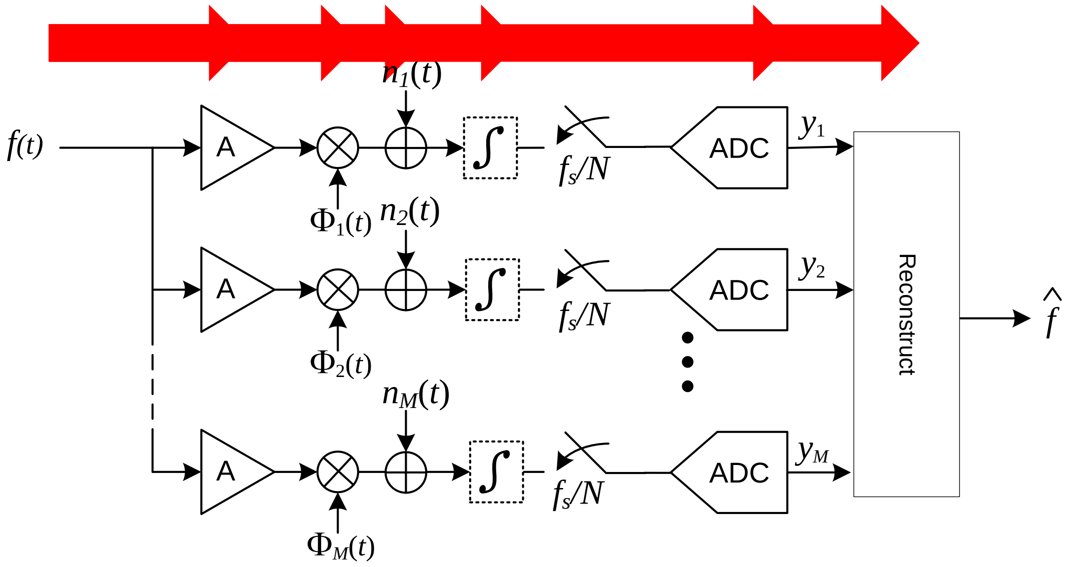




$$n_i(t) = f(t) \cdot N_i(t)$$

- Jitter Noise:
  - Jitter width: ε ~ N(0,σ) , σ is jitter RMS.
  - Spatial correlation: same PLL is used across all measurements

Mixer Jitter affects AIC Measurements



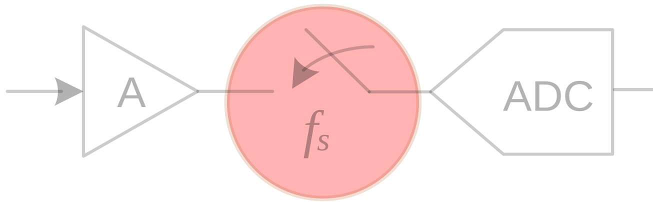
Each measurement, y_i, is computed by:

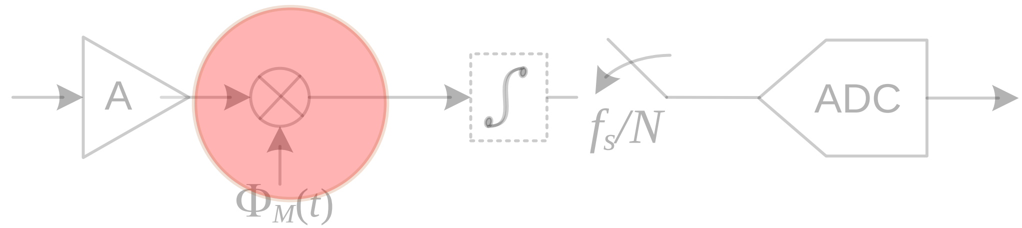
$y_i =$

$n_i(t) = f(t) \cdot N_i(t)$

$$\boldsymbol{y} = \Phi\Psi\boldsymbol{x} + \boldsymbol{n^o}$$ Where: $$\Phi_{ij} = \Phi_i(t)\big|_{t=j.T_s}$$

Aperture Model

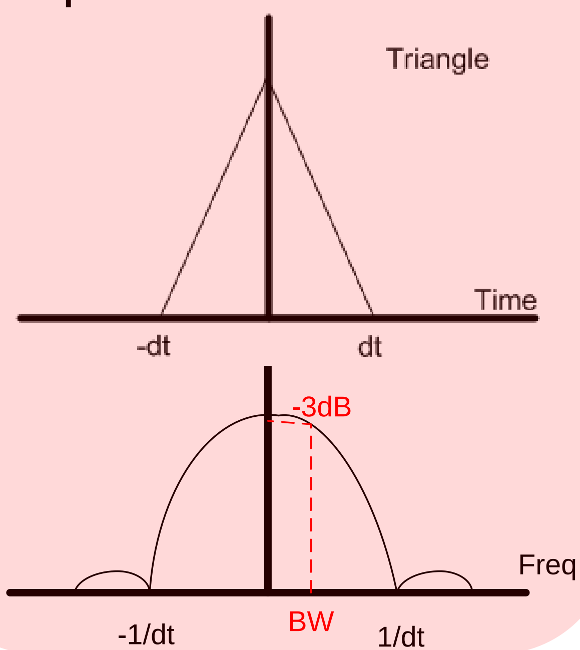


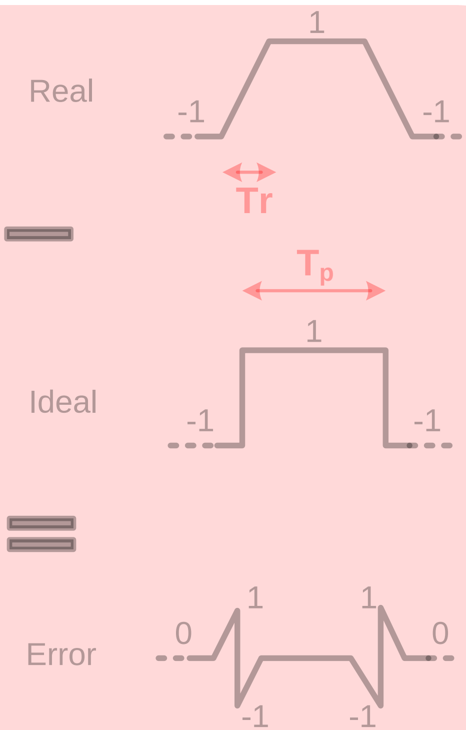


Effects of ADC's bandwidth and clock rise time

Effects of mixer delay and PN sequence rise time

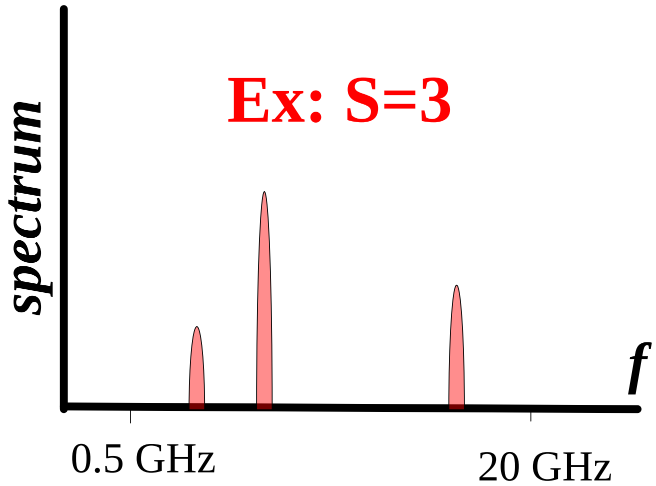
Sampler Transfer Function





AIC Framework for Cognitive Radio

- Cognitive radio environment:
  - Observe the entire frequency spectrum: 500MHz-20GHz
  - Determine the location of used channels: N=1000 channels
  - Only S << N users are "active" at any one time

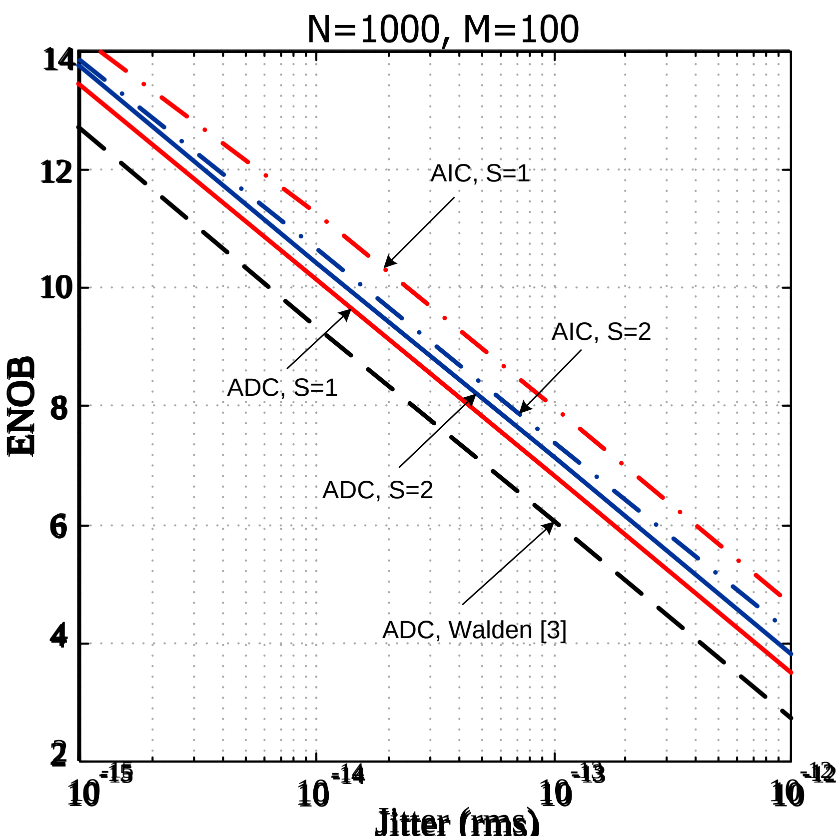


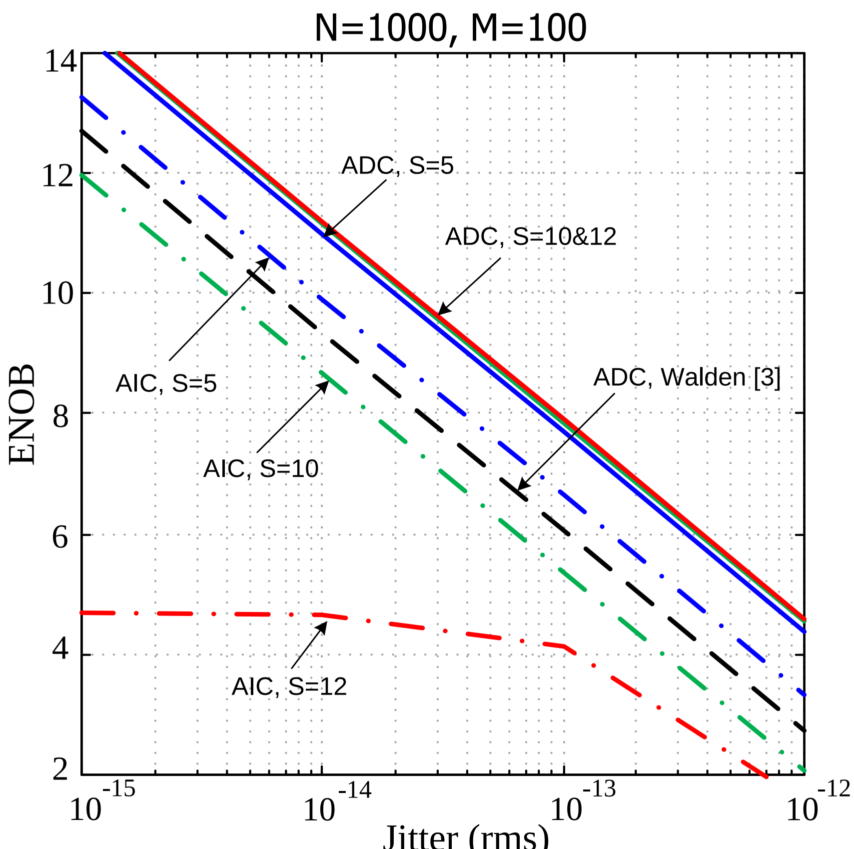
- Signal Model:

$$f(t) = \sum_{j=1}^{N} x_j \sin(\omega_j t) \quad \text{where } x \text{ is sparse}$$

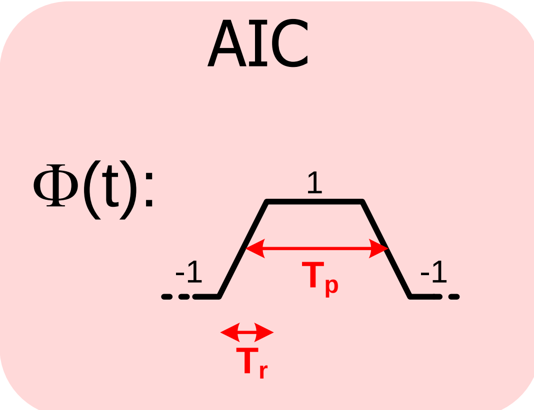
AIC Have Marginally Better ENOB

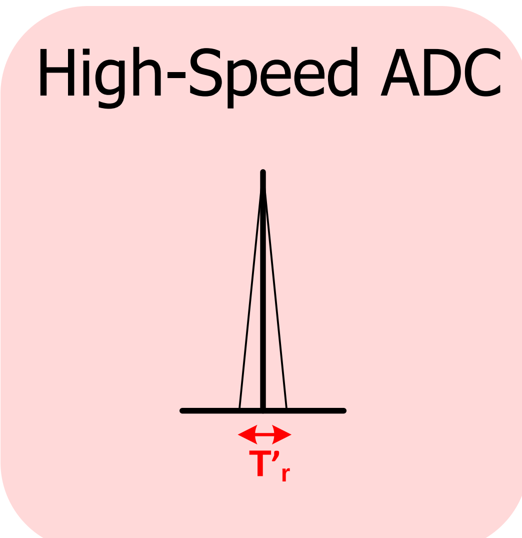
- As sparsity level S increases:
  - ADC performance improves
  - AIC performance worsens
- AIC marginally better for small number of components (S)

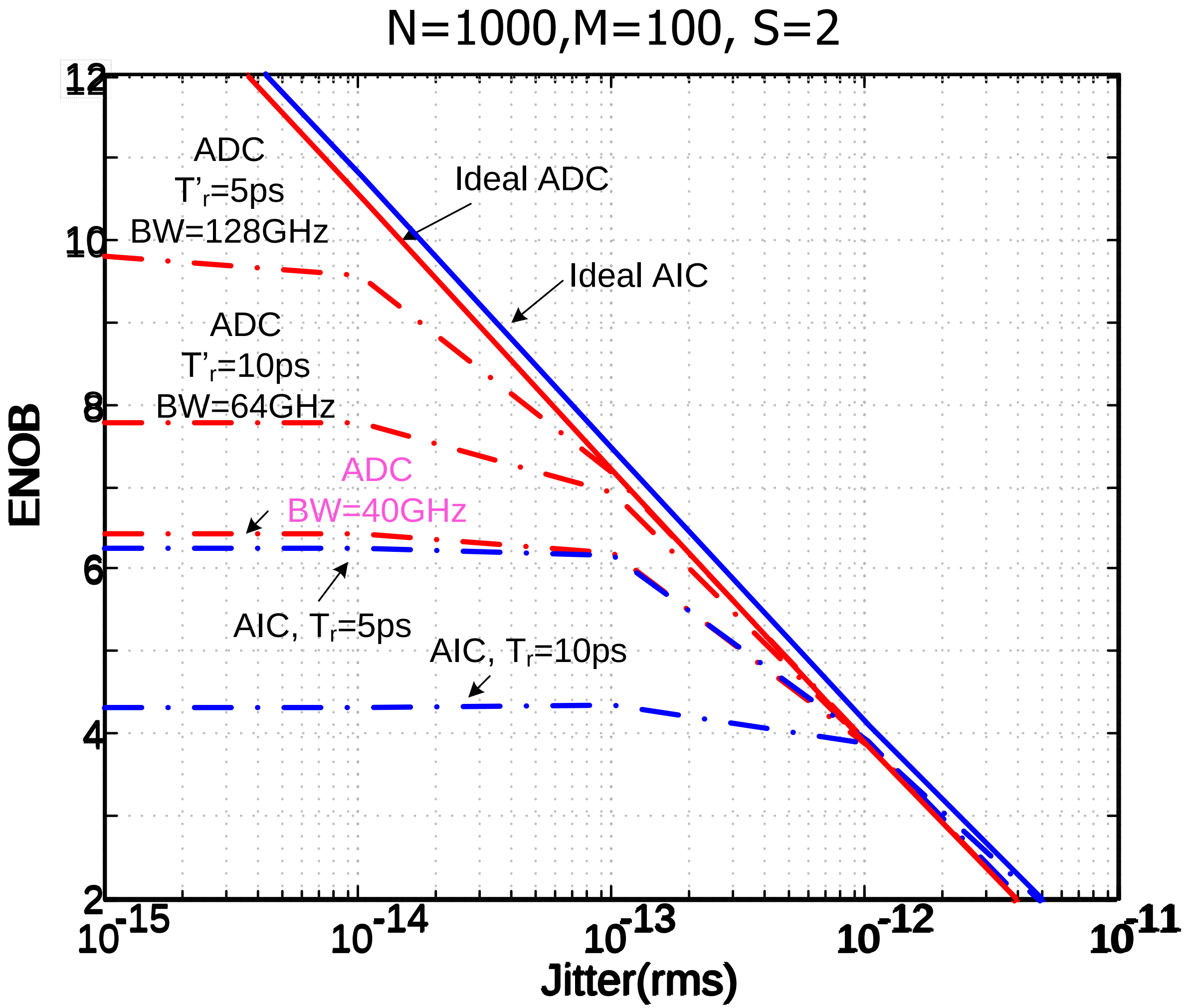




Aperture Affects ENOB of AIC and ADC



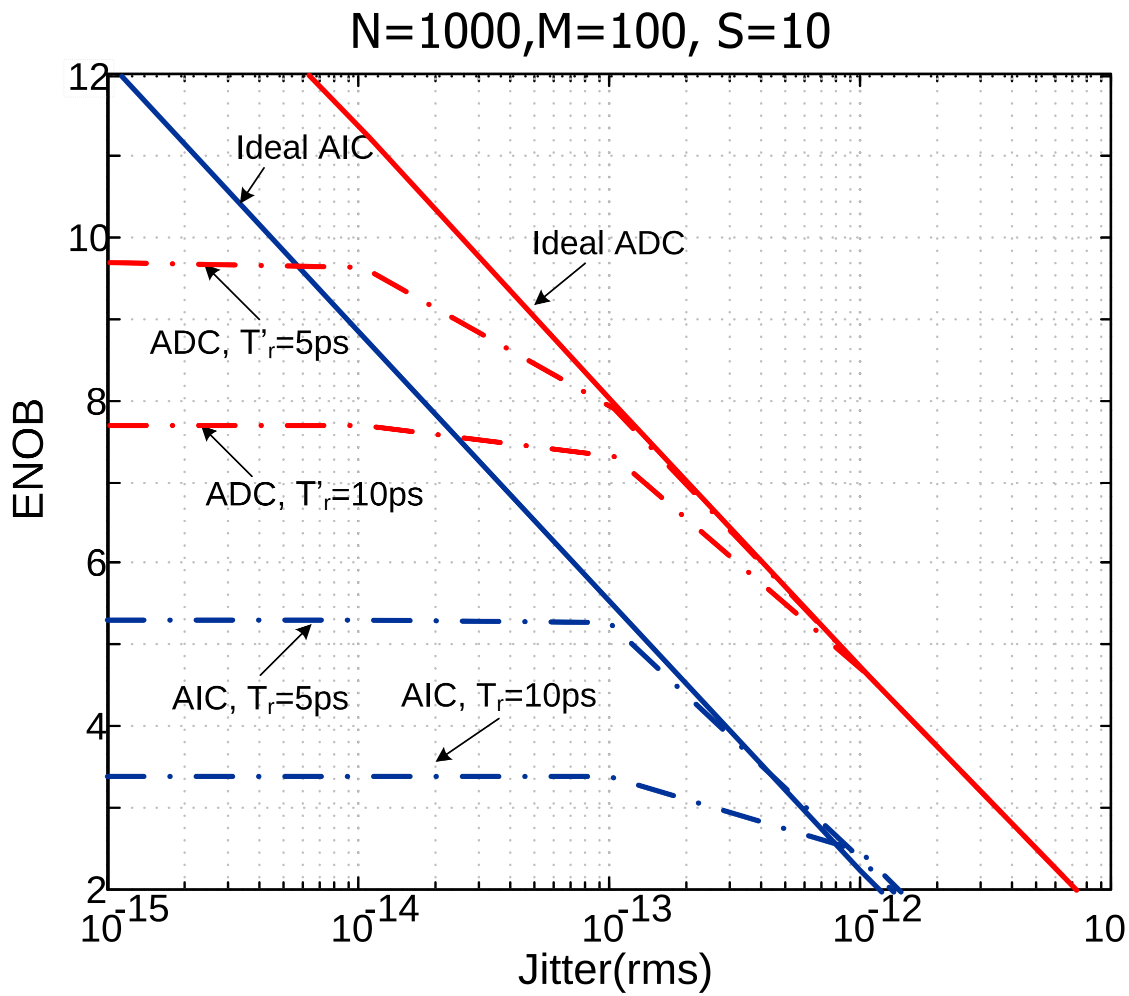




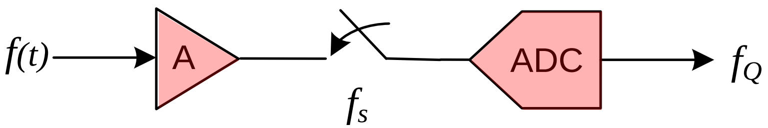
- Aperture and mixer delay worsen ENOB in high-speed ADC and AIC, respectively.

APERTURE EFFECTS

- Aperture and mixer delay worsen ENOB in high-speed ADC and AIC, respectively.

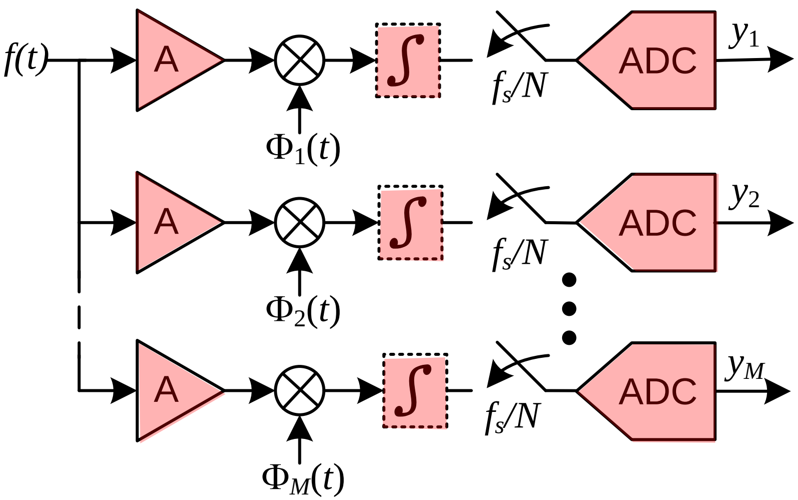


AIC & High-Speed ADC Power Model



P_{ADC} =

Tunable Parameters: **ENOB** | **G_A**

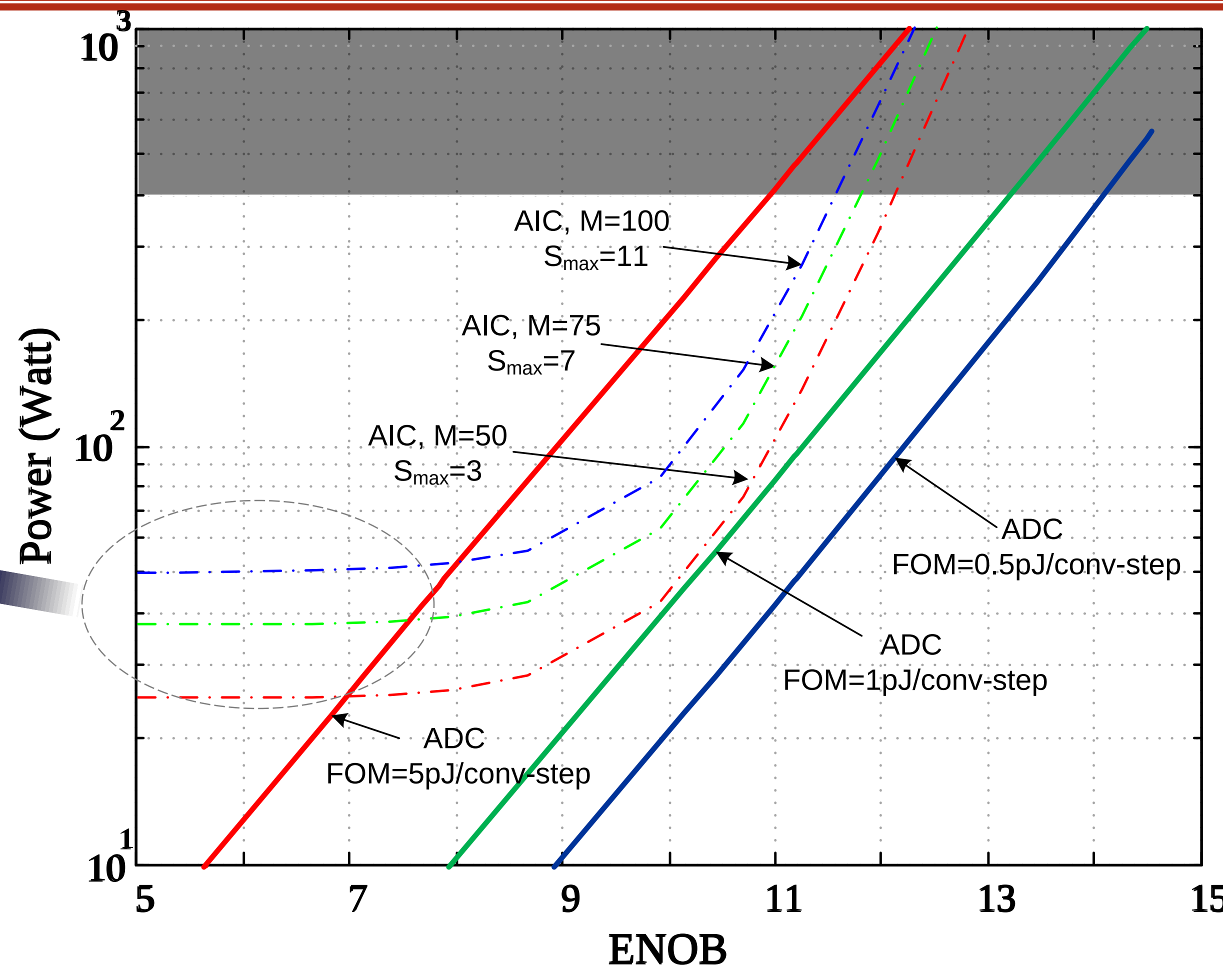


P_{AIC} =

Tunable Parameters: **ENOB** | **G_A** | **M** | **N**

POWER CONSUMPTION-M

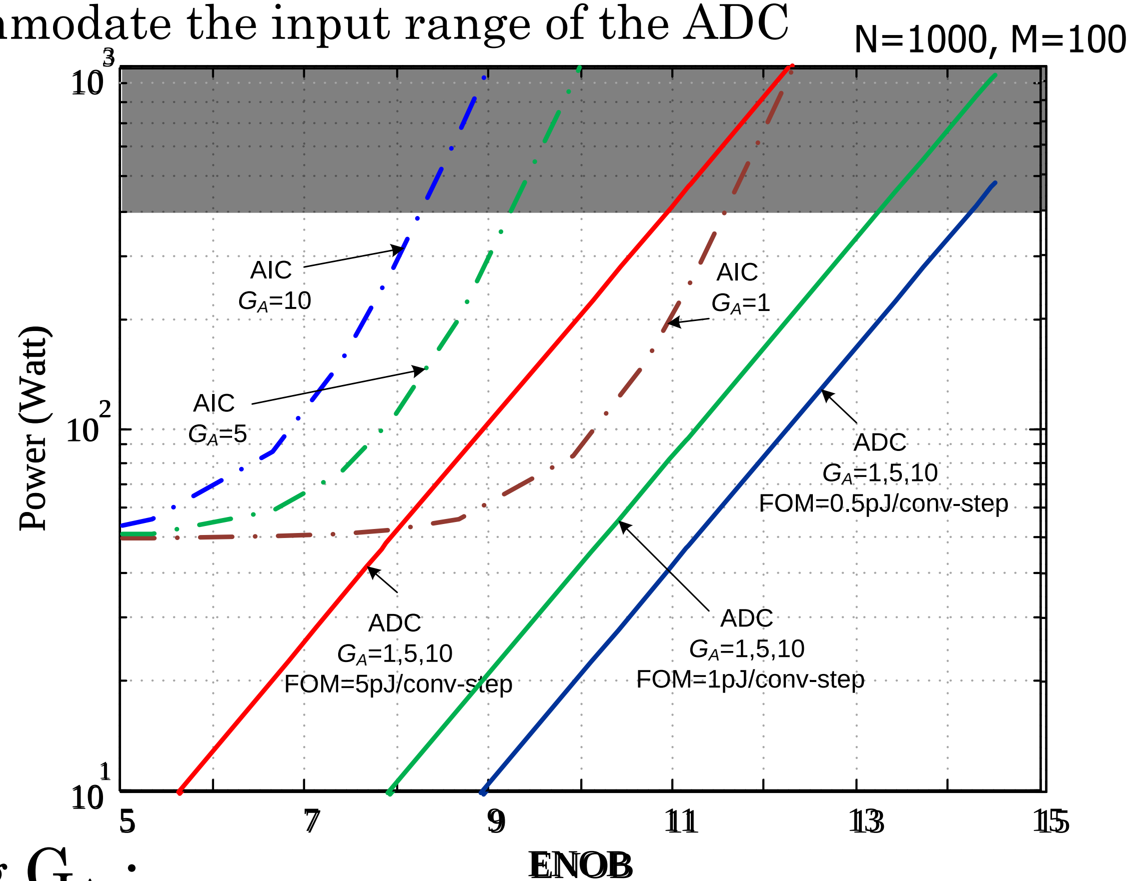
- Dominated by the integrator power, not a function of ENOB



- Increasing number of measurements, M:
  - Allows reconstruction of more components (S)
  - Increases the AIC power

POWER CONSUMPTION-G_A

- System Gain (G_A) varies for different applications:
  - To accommodate the input range of the ADC



- Increasing G_A :
  - High-speed ADC power changes very little: Single amplifier is not dominant
  - AIC power increases: Amplifiers power is dominant

Conclusions

- Compared the energy cost and performance limitations of AIC and Nyquist ADC systems in the context of cognitive radio applications .
- Jitter and Aperture in the mixer stage limit the performance of the AIC system.
- No significant performance benefits over High-Speed ADC, even at low sparsities.
- AICs enable roughly a 2x reduction in power when no pre-amplification is required.