AQuRate: MRAM-based Stochastic Oscillator for Adaptive Quantization Rate Sampling of Sparse Signals

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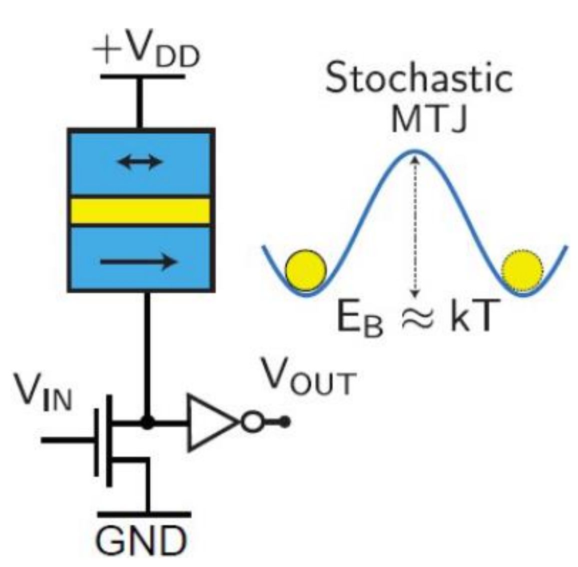
Abstract

- **Proposed Adaptive Quantization Rate (AQR) Generator:**
  - A non-uniform clock generator
  - Leverages Magnetic Random Access Memory (MRAM)-based stochastic oscillator devices
  - ~25-fold reduction in area
  - ~6-fold reduced power dissipation

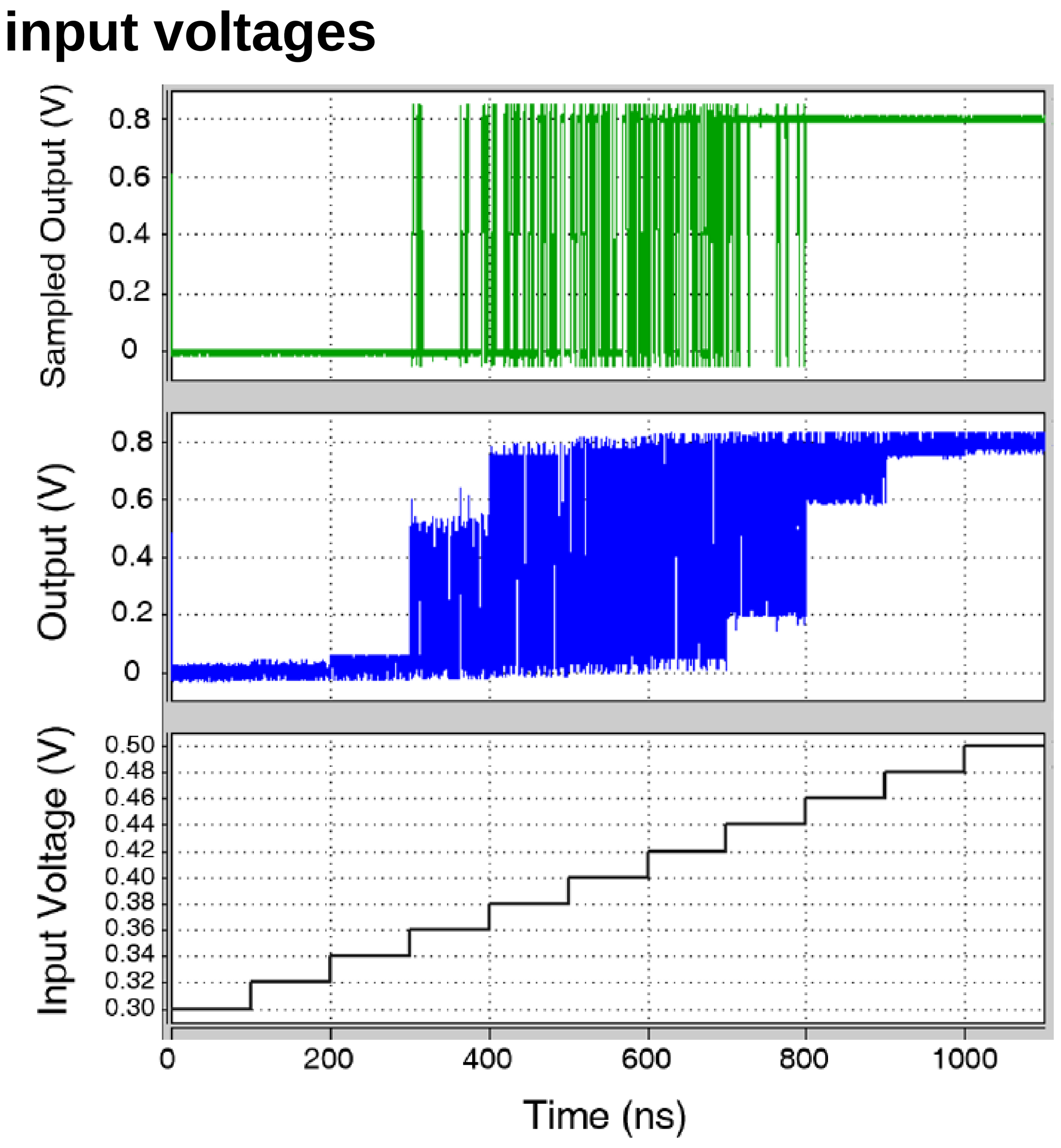
MRAM-based Stochastic Device

- **Probabilistic Spin Logic Device (p-bit) [1]**

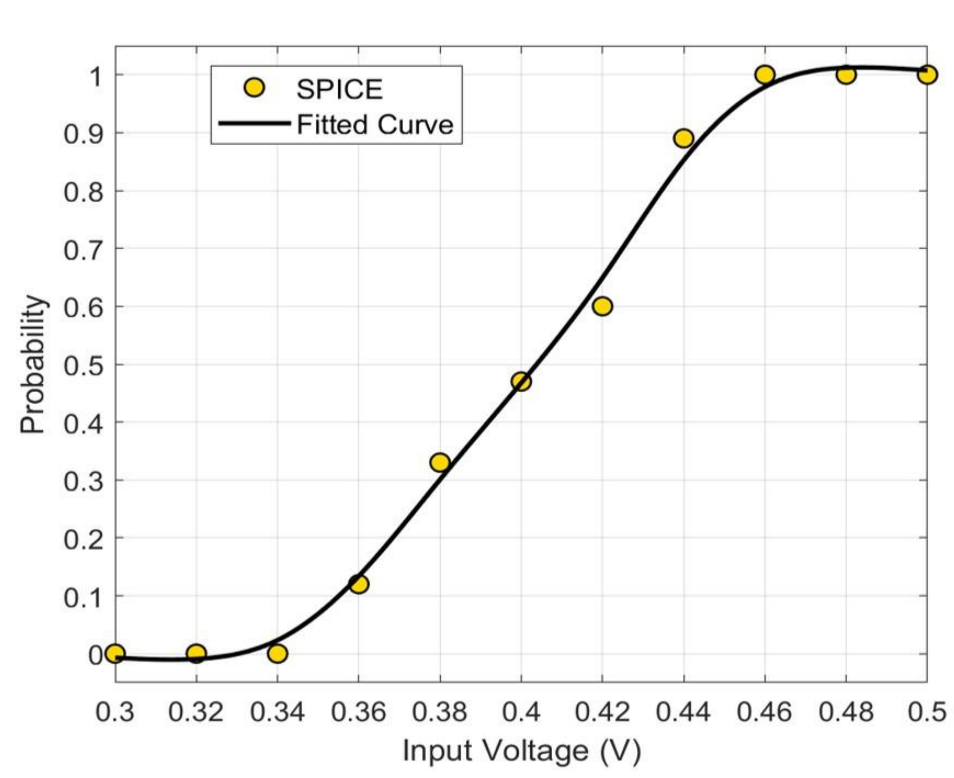


- V_{IN} controls the resistance of the transistor to regulate the output voltage to provide a stochastic oscillator device as a building block for the proposed AQR generator.

- **The sampled output of the p-bit for AQR generator for various input voltages**

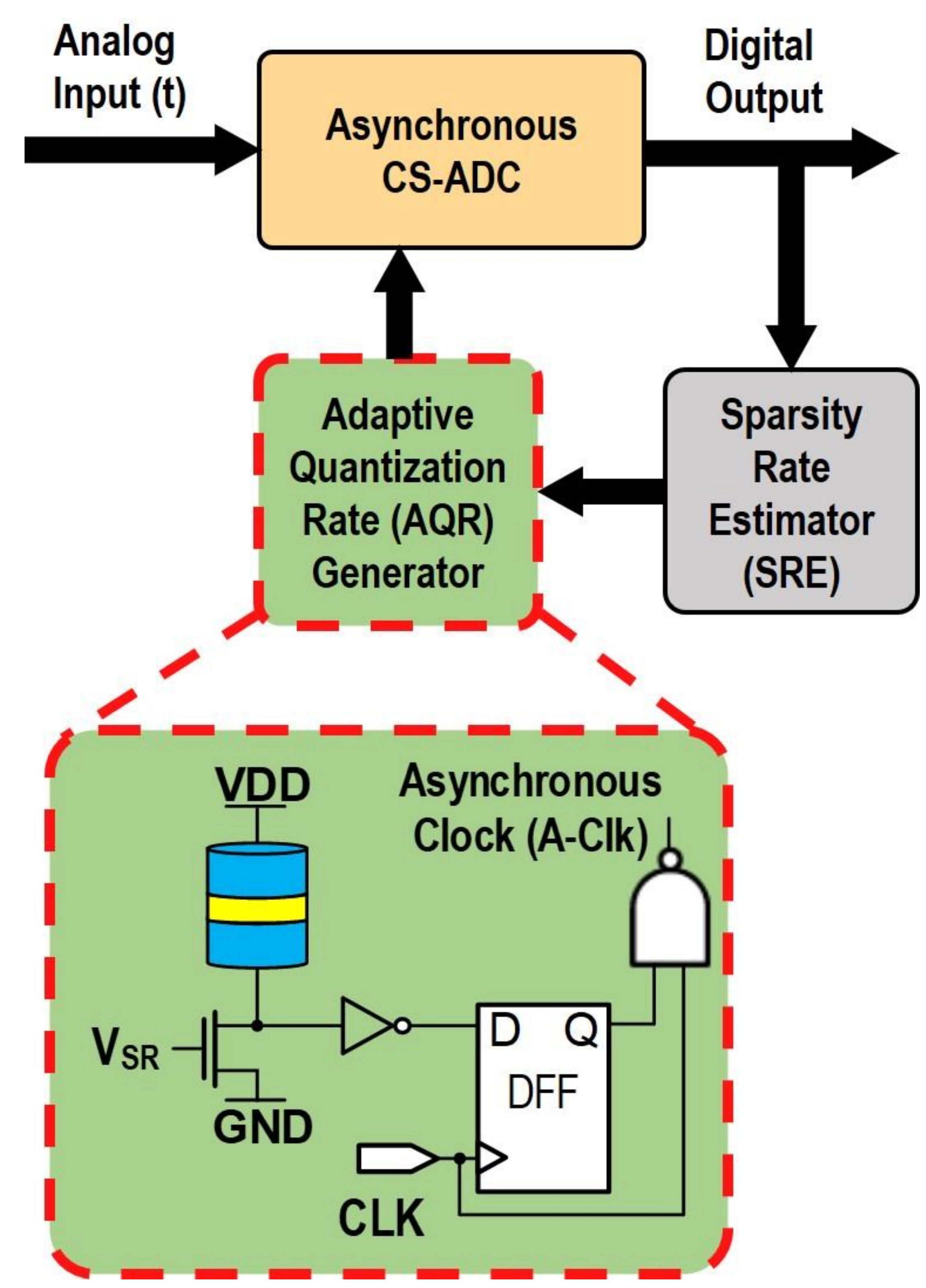


- **Output probability of p-bit vs. its input voltage**



Adaptive Quantization Rate (AQuRate)

- **Integration of AQR generator circuit in the Compressive Sensing Analog to Digital Converter (CS-ADC) system**



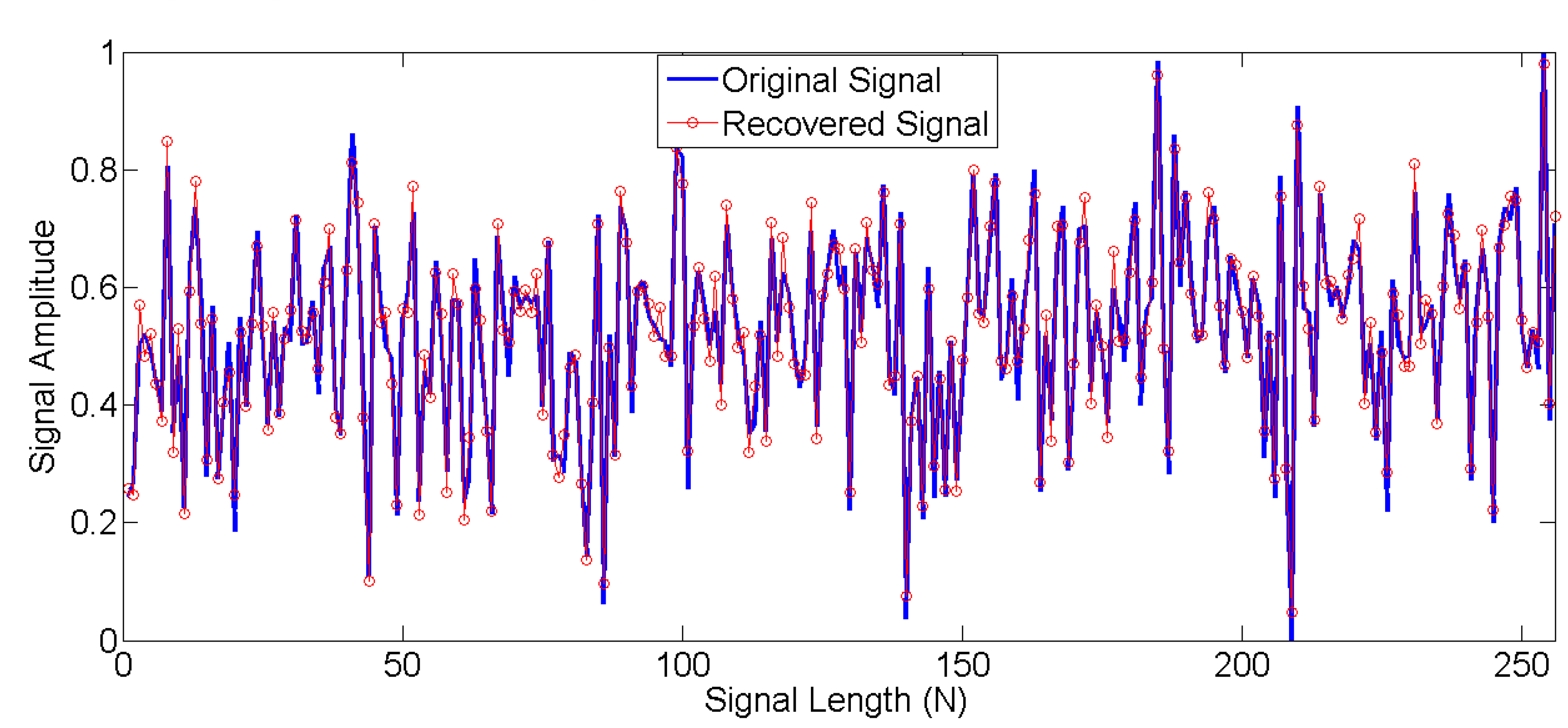
SPICE and MATLAB Simulation Results

- **Comparison Between AQR and recently proposed non-uniform clock generator designs**

Design	Technology ($V_{nominal}$)	$Power_{norm}$	$Area_{norm}$
[11 [2]	65nm (1.1V)	~ 1×	~ 1×
[13 [3]	65nm (1.1V)	~ 2×	~ 21×
[4] [4]	90nm (1.2V)	~ 2×	~ 51×
[3] [5]	28nm (1.0V)	~ 18×	N/A
This Work	14nm (0.8V)	1×	1×

$$Power_{norm} = \frac{Power_x}{Power_{AQR}} \times \left(\frac{1}{U}\right)^2 \qquad Area_{norm} = \frac{Area_x}{Area_{AQR}} \times \left(\frac{1}{S}\right)^2$$

- **Recovery of an sparse signal with sparsity rate of 10% using CoSAMP [8] and samples taken by AQR generator output (MSE=0.0304)**



References

[1] K. Y. Camsari, S. Salahuddin and S. Datta, "Implementing p-bits With Embedded MTJ," in *IEEE Electron Device Letters*, vol. 38, no. 12, pp. 1767-1770, Dec. 2017.
[2] H. Lee, C. Grezes, A. Lee, F. Ebrahimi, P. Khalili Amiri and K. L. Wang, "A Spintronic Voltage-Controlled Stochastic Oscillator for Event-Driven Random Sampling," *in IEEE Electron Device Letters*, vol. 38, no. 2, pp. 281-284, 2017.
[3] M. Osama, L. Gaber and A. Hussein, "Design of high performance Pseudorandom Clock Generator for compressive sampling applications," *2016 33rd National Radio Science Conference (NRSC),* Aswan, 2016, pp. 257-265.
[4] R. Z. Bhatti, K. M. Chugg and J. Draper, "Standard cell based pseudo-random clock generator for statistical random sampling of digital signals," *2007 50th Midwest Symposium on Circuits and Systems*, Montreal, Que., 2007.
[5] D. Bellasi, L. Bettini, T. Burger, Q. Huang, C. Benkeser and C. Studer, "A 1.9 GS/s 4-bit sub-Nyquist flash ADC for 3.8 GHz compressive spectrum sensing in 28 nm CMOS," *in IEEE 57th International Midwest Symposium on Circuits and Systems (MWSCAS)*, College Station, TX, pp. 101-104, 2014.
[6] A. Zaeemzadeh, M. Joneidi and N. Rahnavard, "Adaptive non-uniform compressive sampling for time-varying signals," *2017 51st Annual Conference on Information Sciences and Systems (CISS)*, Baltimore, MD, pp. 1-6, 2017.
[7] S. Salehi, M. B. Mashhadi, A. Zaeemzadeh, N. Rahnavard and R. F. DeMara, "Energy-Aware Adaptive Rate and Resolution Sampling of Spectrally Sparse Signals Leveraging VCMA-MTJ Devices," *in IEEE Journal on Emerging and Selected Topics in Circuits and Systems*, vol. 8, no. 4, pp. 679-692, Dec. 2018.
[8] D. Needell and J. A. Tropp, "CoSaMP: iterative signal recovery from incomplete and inaccurate samples," *Communications of the ACM*, vol. 53, no.12, pp. 93-100, December, 2010.

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