A Spin-based Analog to Digital Converter Interactive Simulation Framework

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***Abstract*— With the advent of advanced signal processing techniques and spin-based devices using novel Analog to Digital Converter (ADC) architectures, a novel framework for simulating spin-based ADCs is developed. This proposed simulation framework, called Spin-based ADC Interactive Simulator has been developed to provide insights on use of commercially-available 2-terminal Magnetic Tunneling Junction (MTJ) devices to implement adaptive non-uniform Compressive Sensing (CS) techniques for both technical and educational purposes. MTJ devices can facilitate adaptive CS techniques using non-uniform sampling while reduction in energy consumption of sampling operations, storage, and data transmission overheads. An interactive simulation framework is developed to allow the user to fully-manipulate simulation setup and parameters associated with the spin-based devices. This provides a mean for the users to perform various simulation runs using different parameters to observe the behavior of the Spin-based ADCs under a variety of scenarios and test cases. The simulation results include energy consumption of each spin-based device along with signal transition illustrations of each device at various sampling intervals. Moreover, links to additional educational resources are provided to further the understanding of the Spin-based ADCs being modeled. Future work includes development of educational content for engagement and attraction of high school students into STEM-related fields and an export functionality that enables extracting the results to create spreadsheet documents.**

***Keywords*— Sampling Rate, Quantization Resolution, Compressive Sensing, Magnetic Tunnel Junction, Beyond-CMOS Devices, Analog to Digital Converter (ADC).**

1.0 Introduction

With the commercialization of beyond Complementary Metal Oxide Semiconductor (beyond-CMOS) computing devices, new tools and techniques to realize efficient and reliable circuits that use them and extend previous validated circuit resilience approaches are sought [1-9]. Spin-Transfer-Torque based Magnetic Tunnel Junctions (STT-MTJs), have been recently commercialized after being explored by researchers for many years. STT-MTJs are suitable for applications such as nonvolatile memory due to their near-zero power consumption, area efficiency, and fast read operation [7]. STT-MTJs contribute valuable properties such as non-volatility and stochasticity, allowing them to be suitable for diverse applications [1-3,7]. However, currently, these devices are not widely-integrated into the educational curriculum of many Electrical and Computer Engineering undergraduate degree programs.

2.0 System Overview and On-going Work

Viable educational approaches and simulation-based systems are helpful to explain the operation of electronic devices and their application via hands-on activities, often integrating teaching with recent research approaches [11-15]. One such approach is described in the poster abstract above which is an on-going effort to develop an interactive simulation framework to allow the student users to fully-manipulate simulation setup and parameters associated with selected spin-based devices. Besides these web-based tools, chatbot-style interfaces that support conducive interactions [17-18] are a longer-term outcome worth pursuing, while providing an Intelligent Tutoring System backend to guide the learning process [19].

Spin-ADC Interactive Simulator provides a Graphical User Interface (GUI) that allows for the modification and insertion of values for Spin-ADC simulations. Figure 1 illustrates the GUI designed for the proposed simulation framework. Default parameter values reflect simulation cases used in [1]. Additionally, device parameters can be modified for running different simulations considering various scenarios. Moreover, the run option compiles all parameters and simulation options to display simulation results in form of visualized graphs. For each simulation run, the results are displayed in a separate GUI window. Figure 2 depicts sample output shown for a

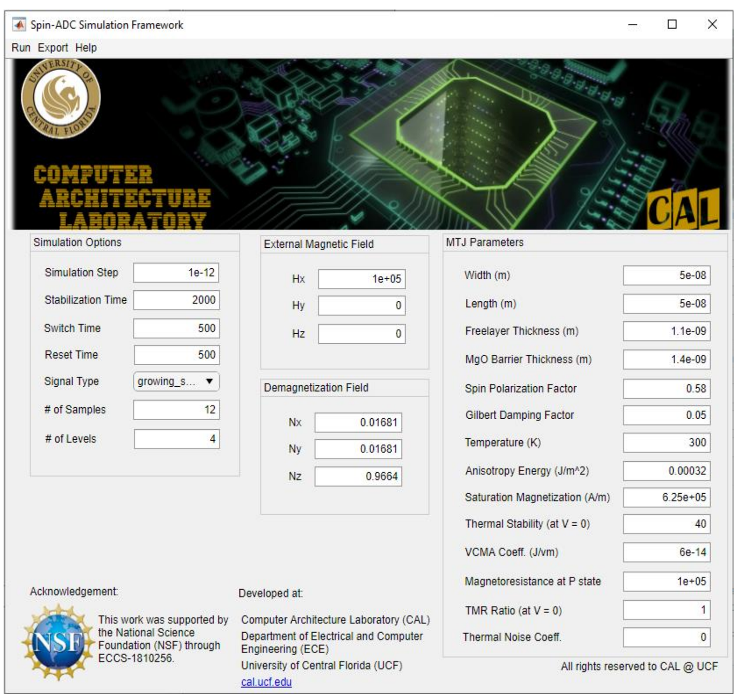

Figure 1: Web-based interface of simulation framework.

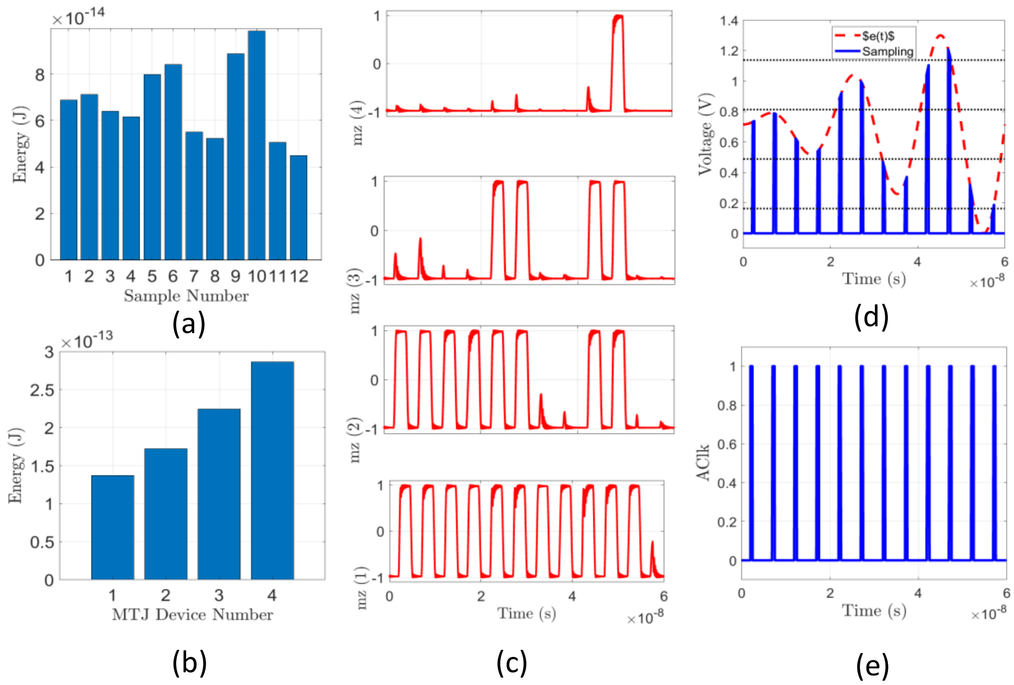

Figure 2: Sample output of the proposed simulation framework: (a) depicts energy consumed for each sample, (b) illustrates energy consumed by each MTJ, (c) shows magnetization orientation of each MTJ, (d) demonstrates analog input waveform, and (e) visualizes sampling rate.

simulation run using the proposed framework. Furthermore, we have provided a help menu that redirects to various educational resources site for more information.

3.0 Conclusion

Herein, we developed an interactive tool for simulating a Spin-based ADC design, which is based on our previous research findings. We plan on utilizing our simulation framework in undergraduate and graduate coursework as well as to engage and attract high school students into STEM-related fields. The poster itself with full graphical information is available as a stand-alone pdf file. Please refer to the poster pdf file for full website information and screenshot figures. The website URL for these materials and the simulation framework itself is: http://cal.ucf.edu/ccsser.html. The work highlighted in the poster pdf file reflects the system at the time of publication, while the website continues to be updated with additional features.

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