

Topics for a Diplomarbeit

Simulation of a fully analog memristive neural network accelerator

At the Chair of Fundamentals of Electrical Engineering novel memristive and memcapacitive memory elements are investigated to enable non-conventional low-power analog computing systems [1]. These memristor devices have internal memory functions like a RAM and can be used in crossbar structures for highly parallel computations, especially for matrix multiplications, as they are massively used in artificial neural networks (ANN) [2]. It has been shown experimentally at NaMLab gGmbH [3], that memristors based on niobium oxide can feature multi-level analog switching for emulating neural synapses, as well as local activity based on negative differential resistance (NDR) for mimicking activation functionality of neurons. Consequently, these memristors can be implemented for a fully analog memristive neural network accelerator in a neuromorphic circuit. However, several non-ideal properties of the devices, such as their dynamic range, indistinguishable memory states, reliability, and degradation must be considered for optimal application in the crossbar networks as well as for the neuron circuit. Within the scope of a scientific work, a simulation of a neural network accelerator including memristive synapses as well as memristive neurons is developed applying available circuit theoretic models and investigating the applicability for a ANN computation considering real non-ideal memristive characteristics.

The student research project or thesis should include, but not be limited to, the following:

- Literature research on memristive crossbars and memristive neurons
- Simulation of both, memristive crossbar and memristive neuron circuits, based on available circuit models, e.g. NamLab's niobium oxide memristors
- Demonstration of a fully analog memristive ANN accelerator
- Investigation of different network sizes, performances and limitations towards its simulation and a real circuit realization
- Documentation of the results

For this thesis a very good knowledge of the basics of electrical engineering, system theory as well as programming (Python, Matlab and/or SPICE) is required. In-depth knowledge of memristive crossbars and memristive neurons can be acquired in the course of the student research project/diploma thesis.

References:

- [1] Tetzlaff, Ronald. *Memristors and Memristive Systems*. Springer, 2014
- [2] Wang, Zhongrui, et al. "Fully Memristive Neural Networks for Pattern Classification with Unsupervised Learning." *Nature Electronics*, vol. 1, no. 2, 2018, pp. 137–45.
- [3] Mikolajick, T., et al. "Versatile Resistive Switching in Niobium Oxide." 2016 IEEE International Symposium on Circuits and Systems (ISCAS), 2016, pp. 381–84.

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