

Topics for a

Studienarbeit or Diplomarbeit**Investigation of memristive/memcapacitive crossbar structures for power-efficient realization of artificial neural networks**

At the Chair of Fundamentals of Electrical Engineering novel memristive/memcapacitive memory elements are investigated to enable non-conventional low-power analog computing systems. [1]. These memristive/memcapacitive 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]. For the realization of hybrid memristor/memcapacitor-CMOS architectures, efficient models and instruction sets are needed to map neuromorphic computational tasks to crossbar structures using optimized read/write algorithms. Here, non-ideal properties of the devices, such as their dynamic range, indistinguishable memory states, reliability, and degradation must be considered. Based on simulations of the individual memory elements as well as entire crossbar networks, the circuit realization is investigated and their performance in terms of low power consumption, speed and reliability is analyzed as an alternative to conventional Von Neumann computing architectures. Finally, they are used for advanced learning algorithms and ANNs, e.g., in image and speech recognition, and biologically inspired Cellular Nonlinear Networks [3]. Within the scope of a scientific work, a simulation environment for artificial neural networks is to be developed using the models for memristive/memcapacitive memory elements and implemented on the basis of the characteristics of concrete components.

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

- Literature research on the application of crossbar structures for use in ANNs
- General modeling of memristive/memcapacitive building elements and crossbar structures
- Implementation of a simulation environment for ANNs (Matlab or Python)

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

References:

- [1] Tetzlaff, Ronald. *Memristors and Memristive Systems*. Springer, 2014
- [2] Wylezich, Helge, et al. *Integration of Niobium Oxide-Based Resistive Switching Cells with Different Select Properties into Nanostructured Cross-Bar Arrays*. Semiconductor Sci. and Technol., 30(11), IOP Publishing, 2015
- [3] Ascoli, Alon, et al. *System-Theoretic Methods for Designing Bio-Inspired Mem-Computing Memristor Cellular Nonlinear Networks*. Frontiers in Nanotechnology 3, Frontiers, 2021

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