Faculty of Science and Engineering

Profile report: Neuromorphic Circuit-Design Engineer (Neuromorfe Circuit-Ontwerp Ingenieur)

- Discipline: Electronic Engineering/ Neuromorphics/ Physics
- Level: Associate/ Full professor
- Fte: Full time (1,0)

1. Scientific discipline

Neuromorphic Electronics utilizes nonlinear and active electrical components to design circuits and devices for the development of neuromorphic or cognitive systems. It also involves the circuit design and integration of threshold switches, transistors, memristors or other novel devices in order to implement learning at the hardware level.

2. Vacancy

This position is opened by the Board of the Faculty (PT/dja/18/00153) as part of the Center "Groningen Cognitive Systems and Materials", which aims to develop systems and materials for cognitive computing. The position will be embedded in the Zernike Institute for Advanced Materials and falls within the framework of 'Career Paths in Science 3' ('Bèta's in Banen 3'). Please see link for criteria and conditions.

3. Selection committee (BAC)

Prof. dr. C.H. van der Wal	Scientific Director Zernike Institute and professor Physics of Quantum Devices
Prof. dr. B Noheda	director Groningen Cognitive Systems and Materials and professor Nanostructures of Functional Oxides
Prof. dr. P. Onck	Director of the educational program of the masters Physics and Applied Physics
Prof. dr. B. Jayawardhana	Professor Mechatronics and Control of Nonlinear Systems, ENTEG
Prof. dr. ir. B. J. Kooi	Professor Nanostructured Materials and Interfaces
Prof. dr. T. S. Gotarredona	Professor Microelectronics Institute-Spanish Research Council, U. Seville
F. Westerman	Student member

Advisors:

Prof. dr. J.B.T.M. Roerdink	Scientific director Bernoulli Institute for Mathematics, Computer Science and Artificial

	Intelligence, and professor Scientific Visualization and Computer Graphics
Prof. dr. L.R.B. Schomaker	Professor Artificial Intelligence
Prof. dr. T. Banerjee	Professor Physics of Nanodevices
Dr. J.H.M. van der Velde	Scientific Coordinator Groningen Cognitive Systems and Materials and secretary of the selection committee

HR advisor:

A.M. van der Woude

4. Research area

Miniaturization and denser packing of Si-based (CMOS) transistors and other components in computing systems is reaching its limits. This is mainly due to the von Neumann architecture of current computers, where the memory and processing units are separated both logically and physically. Here, electrical interconnections are used for communication between the two and have become a bottleneck for performance and the main source of power dissipation. These problems can be addressed by incorporating so-called memristors (or memory resistors), which can act both as memory cells and as switching circuits. Memristors are simple two-terminal resistors, whose resistance can be changed by the charge that passes through them, where the resistance level serves as stored memory. Memristors can also be interconnected to perform Boolean operations.

Memristor-based structures hold the promise of enhancing the speed and power of digital computing beyond Moore scaling, while maintaining compatibility with standard CMOS technology. From an architectural point of view, memristor-based circuits can lead to innovative memory-intensive computing structures and systems and are key to the development of neuromorphic/cognitive hardware.

Next to the development of the memristive devices, electrical engineering expertise is needed for the development of memristor-based applications at the circuit and architecture levels. Thus, memristors are investigated from the point of view of the circuit designer and computer architect, including a description of the desired device for different applications. Memristor-based logic circuit design is acquiring increasing relevance among the electrical engineering community. Different circuit design approaches have been put forward and, recently, those based on collective memristive dynamics are considered most promising. Memristor-based logic circuit design strategies have evolved from sequential logic up to design schemes that support parallel signal processing.

The new staff member will work closely with experts in memristive devices towards the development of cognitive chips/systems that are particularly designed for the specific characteristics of new materials.

5. Embedding: institute (and base unit)

The group Neuromorphic Circuit Design will be established within the Zernike Institute for Advanced Materials as a new research group and will play a crucial role within the Center "Groningen Cognitive Systems and Materials".

The Groningen Cognitive Systems and Materials Center is a joint venture between FSE-institutes Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence, and the Zernike Institute for Advanced Materials. It comprises researchers from materials science, physics, chemistry, mathematics, computer science and artificial intelligence. The center provides structure, coherence, and visibility for a joint research program in the direction of cognitive systems and materials. The main goal of the Groningen Cognitive Systems and Materials Center is to create self-learning materials that will perform the tasks that are now assigned to thousands of transistors and complex algorithms in a more efficient and straightforward manner, hence, forming the basis for a new generation of computer platforms for cognitive applications, such as pattern recognition and analysis of complex data.

The Zernike Institute for Advanced Materials is one of the leading institutes in the field of materials science. Its goal is to design, build and connect nanostructured and (bio)functional materials to achieve unprecedented functionality.

6. Local and (inter)national position

The Neuromorphic Circuit Design group will occupy a unique position both at the national and international level, being part of the research initiative "Groningen Cognitive Systems and Materials" center, which focuses on a new line of research. It will be complementary to, and will work in close collaboration with the newly established Brain-inspired Device group. Additional collaborations will be with other groups working on memristive materials, such as the Nanostructures of Functional Materials group, the Nanostructured Materials and Interfaces group, the Physics of Nanodevices group and the Photophysics and Photoelectronics groups. The new group will bridge the gap between the device development existing in the Zernike institute and the computer science and artificial intelligence expertise that already exist within the Faculty of Sciences and Engineering (FSE): the Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence. Within the Faculty of Science and Engineering, it is expected to have fruitful interactions with the electrical engineering groups in the Engineering and Technology Institute Groningen (ENTEG), and in particular the Discrete Technology & Production Automation (DTPA) group.

In the Netherlands only few efforts in this direction have started to take place. Perhaps the most comparable research group in the Netherlands is the Circuits and Systems group (TU Delft) concentrating mostly on the theory and applications of signal processing, including high-level digital system design, and less on the experimental design and applications. The related Electro-Optical Communication Systems (ECO) group (TU Eindhoven) rather focusses on photonic integrated circuits for Neuromorphic Computing. Most of the other circuit engineer

groups within in the Netherlands can be described as more general electronic engineering research groups.

Internationally, industrial research organizations, such as IBM, HP and IMEC, are moving strongly into the direction of so-called neuromorphic computers in parallel to their efforts in quantum computing. Additionally, there is the EU-Human Brain Project (a H2020 FET Flagship Project) in which the aim is to construct two large-scale, unique neuromorphic machines and prototyping the next generation neuromorphic chips. The machines and chips are, however, based on classical silicon-based materials. Comparable academic research groups are the research groups of Elisabetta Chicca (CITEC/Bielefeld University), Giacomo Indiveri (UZH/ETH Zurich) or Bernabe Linares-Barranco (IMSE, CNM-CSIC Sevilla) and, among the younger groups, Martin Ziegler (CAU, Kiel). These research groups are using standard VLSI CMOS technology and memristive devices. Additionally, important efforts are taking place in China and Japan (AIST being a strong contender) as well as the US (*e.g.* Ivan Schuller is developing a large initiative on memristors for neuromorphic computers in the US, in which also circuit design plays an important role).

7. Expected contributions to research

The candidate is expected to initiate and develop an internationally leading research programme in the field of neuromorphic circuit engineering. The research should have a visibility at the international level and lead to publications in top journals. Further it is expected that the new professor will take a leading role in the field of neuromorphic circuit design within The Netherlands. The research is also expected to find collaborations and cross-fertilize with the existing research within both the Groningen Cognitive Systems and Materials center and the Zernike Institute and should lead to a strengthening of the international reputation of the research center and the institute. Obtaining substantial external funding for PhD projects is crucial. Supervision of PhD students is an important part of the research activities.

8. Expected contributions to teaching

The candidate is expected to contribute to the teaching programmes in the bachelor and master degree programs within the Undergraduate and Graduate Schools of Science and Engineering. She/he is expected to participate in the teaching programme of specialized courses in relation to neuromorphic circuit engineering and other related topics, whose expertise is currently less represented in the faculty, *e.g.* electrical engineering, electronics, neuromorphic engineering, circuit engineering, *etc*. Furthermore, the candidate will be involved in supervising bachelor, master and PhD students.

Upon appointment, depending on experience and formal qualifications to date, the candidate may be required to enter a nationally standardized tertiary teaching skills certification trajectory (BKO or Basis Kwalificatie Onderwijs), successful completion of which is a condition for extensions and tenure.

9. Expected contributions to the organization

The candidate is expected to have an active interest and to provide a positive contribution to the management and organizational tasks of the institute. At the level of the FSE, the candidate will contribute to the organization of the faculty, for example by participating in working groups and committees, in the fields of teaching, research and management. The candidate will participate in relevant national and international organizations.