Temperature-Sensitive Spiking Neurons Implemented with Microfabricated Vanadium Dioxide Memristors

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Abstract

Biologically-inspired sensory neurons implemented with phase-change materials like *vanadium dioxide* (VO_2) are able to encode the perceived information into spikes in the time domain. Operating in the analog world without digital conversions and memories, exceptional energy efficiency is promised for these systems compared to ultra-low-voltage CMOS architectures. At UCLouvain, VO_2 *memristors* exhibiting reversible metal-insulator transitions (MIT) have been successfully microfabricated. A circuit made of a VO_2 memristor driven by an appropriate current source (e.g. a MOS transistor) can leverage the MIT to generate continuous voltage spikes. We will distinguish between two operating regimes of the neuron, corresponding to two distinct configurations of the memristor: the *relaxation oscillator*, where the stimulus is encoded in the spike duration; the *stochastic bursting* regime, candidate to achieve higher energy efficiency and more biologically plausible *excitable* behaviour. As will be shown, robust design and implementation of such neuromorphic sensors require thorough understanding and modelling of the material properties and nonidealities, which motivate our multidisciplinary research efforts.

Léopold Van Brandt was born in Belgium, in 1995. He received the B.S. and the M.S. degrees in Electrical Engineering from the Université catholique de Louvain, Louvain-la-Neuve, in 2015 and 2017, respectively, and the PhD degree in Engineering Science for his dissertation entitled “Statistical Analyses of Intrinsic Noise and Variability Effects in CMOS Digital Latches” in 2022. He then worked for two years as a postdoctoral research fellow in the Mathematical Engineering department of the UCLouvain on the project “Thermodynamics of Circuits for Computation”. Since October 2024, he has been leading his own postdoctoral research project entitled “Stochastic Modelling of Present and Future Nonlinear Dynamical Electronic Devices and Circuits”.

His research interests include but are not limited to: nanoelectronics; characterisation and modelling of the noise in nonlinear devices and circuits; circuit simulation theory; circuit reliability assessment (notably CMOS SRAM bitcells); stochastic thermodynamics; analog neuromorphic circuits and sensors, memristive and ferroelectric devices.

The interplay between research and education is one of his major concerns.