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Editorial

Editorial for the Special Issue on "Quantum-Dot Cellular Automata (QCA) and Low Power Application"

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Challenges created by the trend of increasingly reducing the size of transistors have made necessary innovative technologies to limit undesirable impacts on the performance speed and power consumption of future designs. Nowadays, unconventional solutions, such as Quantum-dot cellular automata (QCA) and nanomagnetic logic (NML), have emerged as good alternatives to the classic CMOS technology. What sets them apart is that they exploit on a nanoscale the inevitable nano-level issues of device-to-device interactions. They perform computing, exploiting revolutionary approaches at the nano-level. The QCA technology is based on the charge configuration of individual computing primitives known as "cells." A cell is a system of quantum dots with a few mobile charges. Device switching occurs through quantum mechanical inter-dot charge tunneling, and devices are interconnected via the electrostatic field. QCA devices are implemented using arrays of QCA cells and appropriate clocking schemes for synchronization. Conversely, the NML technology is based on the field-coupled nanocomputing paradigm: information propagates according to the magnetic interaction among devices. NML devices may be implemented using nanoscale magnets and a clocking mechanism to properly propagate information. Circuits are designed by placing nanomagnets in a chain fashion, obtaining wires able to transport information.

Even though it is not always straightforward, in the last few years both the QCA and the NML technologies have received a great deal of attention. However, several improvements and innovations are still required, not only to make these kinds of specialized designs more robust against process variations and thermal noise but also to make the clocking schemes more efficient. This Special Issue of *JLPEA* is dedicated to advances in all aspects of QCA- and NML-based designs, from the introduction of new basic logic functions through to innovative layout strategies.

The paper entitled "Physical Simulations of High Speed and Low Power NanoMagnet Logic Circuits" [1] presents a novel clocking mechanism enabling the independent control of each nanodevice by exploiting the magneto-elastic effect and enabling high-speed NML circuits. The authors prove the effectiveness of this approach by performing several micromagnetic simulations and by characterizing a chain of nanomagnets in different conditions. This solution improves NML, the reliability of circuits, the fabrication process, and the operating frequency of circuits while keeping the energy consumption at an extremely low level.

In another paper entitled "Clock Topologies for Molecular Quantum-Dot Cellular Automata" [2], various arrangements of clocking conductors are laid out, and the resulting electric field is simulated. It is shown that control of molecular QCA can enable feedback loops, memories, planar circuit crossings, and versatile circuit grids that support feedback and memory, as well as data flow in any of the ordinal grid directions.

Professors Pidaparthi and Lent calculate the excess energy transferred into two-dot and three-dot quantum-dot cellular automata systems during switching events [3]. Moreover, they quantify the adiabaticity of a switching event using the adiabaticity parameter of Landau and Zener for both

logically reversible and logically irreversible operations. The exponential decrease in energy dissipation with adiabaticity (e.g., switching time) distinguishes adiabatic quantum switching from the usual linear improvement in classical systems. The key to the proposed approach is calculating the energy delivered as an excitation to the QCA cell. By focusing on the excitation of the system, the switching can be treated as a unitary quantum process, and the complication of including explicit dissipation mechanisms can be avoided.

In the paper entitled "Effectiveness of Molecules for Quantum Cellular Automata as Computing Devices" [4], Professors Ardesi, Pulimeno, Graziano, Riente, and Piccinini define new figures of merit to characterize the molecules, which are based on the post-processing of results obtained from ab initio simulations. These quantities are compatible with an electronic engineering point of view and can be used to analyze the capability of molecules to propagate information. The authors prove that the novel methodology provides the quantitative characterization of the molecules that is necessary for digital designers to design digital circuits, for technologists, and for the future fabrication of molecular QCA devices.

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