Design and Practical Implementation of Memristor-based Threshold Logic Gates

G. Papandroulidakis*, A. Serb, A. Khiat, S. Stathopoulos, L. Michalas and T. Prodromakis

Electronic Materials & Devices Research Group, Zepler Institute,

University of Southampton, SO17 1BJ, United Kingdoms

**Corresponding author Email: g.papandroulidakis@soton.ac.uk*

Current advances in emerging memory technologies enable novel and unconventional computing architectures for high-performance and low-power electronic systems carrying out massively parallel operations at the edge. One emerging technology, ReRAM, also known as memristor, is gathering attention due to its attractive features for logic and memory computing systems. These include nanoscale dimensions [1], low-power operation and multi-state programming [2]. The introduction of memristors has enabled the development of a new era of computing through hybridization of circuit and system design. At the same time, standalone CMOS circuit design seems to have reached its physical and functional limitations. Thus, further research towards novel logic families, such as Threshold Logic Gates (TLGs) is needed. TLGs constitute a logic family known for its high-speed and low power consumption [3]. Although many implementation concepts of TLG circuit are assuming the use of memristors [4], few of them are based on physical ReRAM devices.

In this work, we present the implementation of a memristor-based current-mode TLG (MCMTLG) design, shown in Figure 1. We thus take a step towards realising a compact, VLSI-compatible digital input/output neuron circuit, one of the basic components of memristor/CMOS hardware artificial neural networks (ANNs). Our reconfigurable logic gates are based on metal oxide-based memory cells. Results from a physical implementation of a memory-dependent reconfigurable MCMTLG circuit are shown in Figure 2. This novel implementation is enabled by the recent demonstration of high-resolution multi-state programming capabilities of the memristor devices [2], which allows for practically continuously tuneable analog resistive weights. Such advances along the technological frontier of novel memristive TLG circuits and systems design could offer new impetus to the field of power-optimized digital circuitry, tackling challenges such as CMOS implementations of popular operations like convolution, encryption and other massively parallel bitwise-based operations. Our work thus supports the concept of ANN-based computing systems.

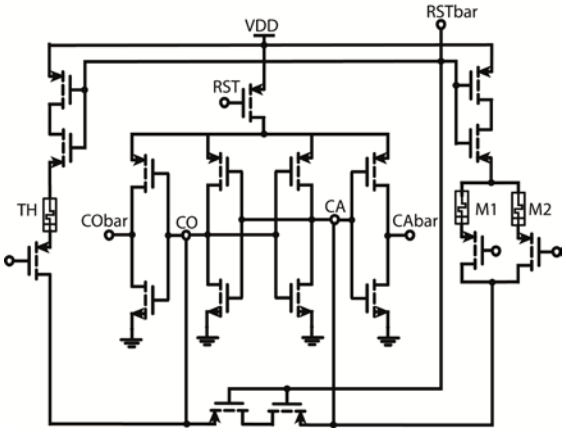

Figure 1: Memristor-based Current-Mode Threshold Logic Gate (MCMTLG) circuit schematic.

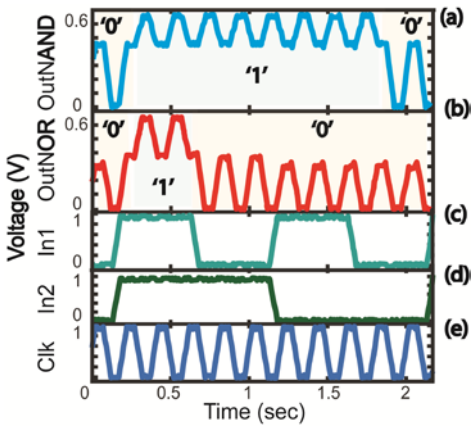

Figure 2: MCMTLG operation as either AND/NAND or OR/NOR. Reconfiguration is based on its memristive memory contents.

References

[1] A. Khiat et al. *Sci. Rep.* **6**(1), 2016

[2] S. Stathopoulos et al. *Sci. Rep.* **7**(1), 2017

[3] C. B. Dara et al. *IEEE Trans. VLSI.* **25**(3), 2017

[4] C. B. Dara et al. *IEEE Int. Symp. On DTFS.*, 2013