Researchers develop a new way for designing electronics

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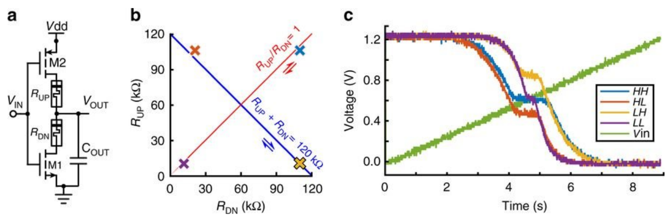

Reconfigurability modalities in an analogue inverter gate. a Memristor-enhanced analogue inverter topology. b Changing the resistive states of the memristors RUP, RDN in the inverter so as to keep their sum (along blue line) or ratio (along red line) constant offers flexibility in controlling the inverter's transfer characteristics. The constant sum modality allows independent control of transfer characteristic's plateau height while the constant ratio modality allows for independent control of the plateau's width (see Supplementary Fig. 4). Colour-coded crosses correspond to the RUP, RDN configurations used in the results of c (see Supplementary Table 2 for details). c Four measured examples of analogue inverter transfer characteristics corresponding to the cases where RUP and RDN are both high (HH), high and low (HL), low and high (LH) and both low (LL), respectively. The measured input voltage during the HH trial is shown in green as Vin (similar for all trials). Note independent modulation of plateau width and altitude by the sum and ratio between RUP, RDN. Credit: *Nature Communications* (2018). DOI: 10.1038/s41467-018-04624-8

A team from the University of Southampton has invented a new way for designing electronic systems that incorporates the best from both analogue and digital paradigms.

The approach combines the computational power of analogue with the energy benefits of digital technologies. This new model alters the current way of thinking and is destined to shape the next generation of electronics.

The study, titled "Seamlessly fused digital-analogue reconfigurable computing using memristors," was published in *Nature Communications*. It revealed how the fusion of analogue and digital thinking can be achieved by combining standard digital electronics—as found in every computer and mobile phone today—with the rapidly emerging technology of analogue memristor devices.

This powerful combination is a significant stepping-stone towards the next generation of ultra-low power, high battery life and adaptable electronics.

Dr. Alexantrou Serb, lead author of the paper from the University of Southampton, said: "Over the last five decades we have processed digital signals and have computed using digital techniques, which has taken us very far.

"However, if we are to truly compute at the limits of energy efficiency, that the laws of physics allow, it would seem imperative that we need to move towards analogue computation techniques whilst being much savvier about how to mix analogue and digital signals for maximum effect."

This work builds on previous developments of memristive technologies undertaken at the University of Southampton. This included the demonstration of a new memristor technology that can pack unprecedented amounts of data per device, almost four times more than previously reported.

Professor Themis Prodromakis, Head of the Electronic Materials and Devices Research Group at Southampton's Zepler Institute, said: "Memristors have gathered a lot of interest as a next generation memory technology by being smaller, more power efficient and yet being able to support more memory states when compared to existing technologies that are routinely used in our smartphones and computers.

"Our group has worked tirelessly in that direction with the support of EPSRC, contributing towards demonstrating more mature and reliable technologies and improving on their performance.

"We soon, however, realised that there is much more to be earned by employing this technology beyond its obvious memory applications and have previously demonstrated how memristors can be used to emulate biological learning."

The capability to pack large amounts of memory cheaply is a key stepping stone towards a new breed of electronics. Traditionally, the processing of data in electronics has relied on integrated circuits (chips) featuring vast numbers of transistors – microscopic switches that control the flow of electrical current by turning it on or off.

In this switch-based concept, memory is an expensive resource used as sparingly as possible. Until now, performance improvements were achieved by reducing the size of transistors and packing more of them in each microchip. However, with transistors now reaching their physical scaling limits, further improvements using the old techniques are becoming increasingly challenging.

A direct impact of this research on modern technologies could be the creation of ultra-efficient artificial intelligence (AI) hardware. AI by nature lends itself to analogue implementation of computation much more readily than to the current digital-based techniques used in our smartphones and the cloud.

The projected power-savings and performance gains from using memristor-based, analogue microchips suggest that this research could one day lead to hardware that exhibits true intelligence without the help of a supercomputer in the cloud, and yet fits in the palm of one's hand.

The resulting proliferation of intelligent agents is capable of disrupting every level of social and economic activity and fundamentally change the daily environment with which we interact.

More information: Alexantrou Serb et al. Seamlessly fused digital-analogue reconfigurable computing using memristors, *Nature Communications* (2018). DOI: 10.1038/s41467-018-04624-8

Provided by University of Southampton