Memristor Technology in Future Electronic System Design

Embedded Tutorial

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***Abstract*--The memristor is a new nano-electronic device very promising for emerging technologies. Although 40 years ago Leon Chua has postulated this circuit element, only the invention of the crossbar latch by the HP group of Stanley Williams provided the first nanoelectronic realization of such a device in 2008. Thus it has been shown that the ideal circuit elements (R,C,L) were not sufficient to model basic real-world circuits. Memristors being essentially resistors with memory are able to perform logic operations as well as storage of information. Recently, it has been announced that "Williams expects to see memristors used in computer memory chips within the next few years. HP Labs already has a production-ready architecture for such a chip" (http://www.hpl.hp.com/news/2010/apr-jun/memristor.html). Memristors are outstanding candidates for future analog, digital, and mixed signal circuits.**

CONTRIBUTORS

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Brains Are Made Of Memristors

In addition to the immense potential economic impact of memristors as a new family of nano-scale nonvolatile memory devices which would replace Flash, DRAM, and SRAM in the near term, this lecture will explain why in the long term memristors would find even more significant industrial applications as nano-scale neuromorphic chips that would significantly outperform current neural networks. The reason is that our brains are made up of two distinct types of memristors; namely, "locally-passive" memristors for learning and long-term memory, and "locally-active" memristors for generating action potentials (spikes), which are essential for intelligent and brainlike information processing. In other words, memristors are the right stuff for building brainlike machines.

Dr. R. Stanley Williams, Palo Alto, USA

The Ionic Drift Memristor - a Universal Memory and Storage Element?

Leon Chua predicted the existence and properties of a new fundamental circuit element in 1971 and named it the memristor, a portmanteau of memory and resistor. Beginning even before that prediction, many researchers had seen evidence of memristive behavior in the current-voltage characteristics of various device structures, but did not know how to interpret the observations. In 2008, my lab at HP Labs published a paper that showed why a titanium dioxide based resistive switch was actually a memristor. Since then, interest in this area and new research results have increased explosively, and many properties of the devices are improving exponentially with time. At this time, the champion device is based on tantalum oxide, which has demonstrate write/erase endurance of over 10 billion cycles with no failures, write and erase speeds and energies of ~100 picoseconds and less than 10 picoJoules, respectively, and state lifetimes stable to several months (as long as the devices have existed). By the time of the conference, it is possible that these properties will have been eclipsed significantly. I will do my best to compare the basic switching properties of ionic drift memristors to those of Flash, DRAM, phase-change memory and spin-torque transfer devices (the last two also belonging to the general class of memristive device). At present, we are working to have a competitor to Flash in the market in a 'couple years' from now, with a DRAM competitor not far behind. We are also examining the potential for integrating memristors directly on processor chips to replace SRAM.

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