Memristors and Related Applications

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Abstract—A memristor is a two-terminal device with a variable resistance that can be used as memory. In 2008, Hewlett-Packard announced that they had succeeded in fabricating a working memristor array. Memristors can be used for many applications, including digital memory, neuromorphic systems, and logic circuits. In this paper, memristor-based applications are reviewed, and the main characteristics of these applications are discussed.

Memristors were first described in 1971 by Leon Chua as "the fourth passive element" (together with a resistor, capacitor, and inductor) in electronic circuits. A current-controlled time-invariant memristive system is represented as

$$\frac{dw}{dt} = f(w,i) \tag{1}$$

$$v(t) = R(w,i) \cdot i(t) \tag{2}$$

where w is an internal state variable, $i(t)$ is the memristor current, and t is time. A memristor is a passive two-port device, with a varying resistance, depending on the total charge flowing through it. It behaves as a memory device, storing resistance as the memorized information. A memristor symbol is shown in Figure 1.

In 2008, Hewlett-Packard announced that they had succeeded in fabricating a working memristor array. Since then, research on memristor-based applications has been growing. Memristors can be useful for memory (Hewlett-Packard announced that in 2013 the first memristor-based memory will be commercialized), neuromorphic systems (brain-like electronic circuits), and logic circuits.

Memristor-based memory is the most obvious application of memristors. One memristor can store a single bit of data in a DRAM-like architecture, where the capacitors are replaced with memristors. This kind of memory has many advantages as compared to SRAM and DRAM; it has no leakage power, is non-volatile, and exhibits good scalability. Memristor-based memory is superior to flash memory in terms of speed and scalability. One memristor can even store more than one bit, in an approach similar to multilevel flash memory.

Memristors behave similarly to biological synapses. This characteristic makes memristors good building blocks in neuromorphic systems, where neurons and synapses are modeled as electronic devices.

Another possible application of memristors is logic circuits. Memristors can be used in hybrid CMOS-memristor circuits, or as a standalone logic gate. One notable logic application is using memristors in an FPGA, as configurable switches, connecting the CMOS logic gates. A different approach is using memristors as building blocks of the logic gate itself. Since memristors are memory elements, a single memristor can be used as the input, output, or computational logic building block. In this approach, the logic state is represented as resistance, where a high resistance is logical state zero, and a low resistance is logical state one. An example of this approach, the IMPLY logic gate, is shown in Figure 2.

Research in the field of memristors is still in its early stages; new applications will soon be developed. There is still a significant need for relevant design methodologies and architectures.

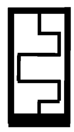

Figure 1. Memristor symbol.

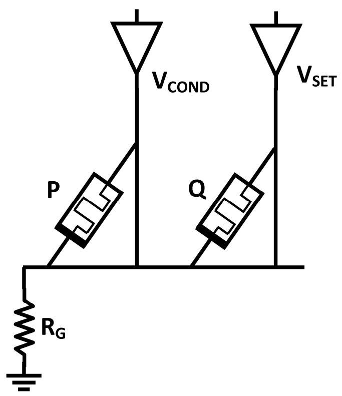

Figure 2. Memristor-based IMPLY logic gate.