Memristors

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1 Introduction

Electronics textbooks list three passive components: resistors, capacitors, and inductors. Resistors relate voltage to current, capacitors relate voltage to charge, and inductors relate charge to magnetic flux. Noting the symmetry (no component relating magnetic flux to current), in 1971 Leon Chua published a mathematical proof [1] that such a device should be possible.

As a function of time, the device gives a flux-charge relationship similar to the current-voltage relationship of a resistor (i.e. its resistance changes according to the charge passed through it). The device remembers it's history, which is where the term "memristor" comes from. Active devices simulating the behavior had existed, but the first passive version came from HP 37 years later. [9]

HP's device consisted of two layers of titanium dioxide (TiO_2), a semiconductor, sandwiched between platinum plates with some oxygen atoms removed from one of the layers to make it conductive (TiO_{2-x}). Voltage applied to the platinum plates would expand or contract the TiO_{2-x} layer, changing the device's conductivity [10] (a switch, essentially).

2 Applications

2.1 Non-Volatile Memory

The device HP created was born out of a research group tasked with figuring out what to do when transistors could be shrunk no further [10]. As component sizes shrink aligning masks during the die creation becomes more difficult and probability of surface defects increase, together reducing yield [8]. The team realized that redundancy could be used to combat the reduced yield. Inspired by another HP project, the Teramac [2] massively-parallel computer, the cross-board latch would be used: multiple switches are placed between an input and output line such that any could trigger a connection. Forming an array of these latches created a storage device, and since memristors preserve their state no power is required to preserve the data.

2.2 Logic

The extension from storage to logic is straightforward: for any operation a given input will produce the same output, so a table of results can be created for a list of inputs. Memristors can implement logic functions as well; the basic NAND gate requires one less component compared to transistors. Besides boolean logic memristors can be used to build the IMPLY conditional ($p \Rightarrow q$) [3] which is useful in implementing fuzzy logic.

2.3 Learning Circuits

A 2009 study[5] showed a simple memristive circuit was able to anticipate voltage spikes when a steady pulse train was applied. The experiment was designed to emulate an earlier study [7] on behavioral intelligence in slime mold. In it the mold was able to predict periodic changes to its environment. A separate study [4] of the slime mold showed the single-cell organisms capable of solving a maze via the shortest path; a network of memristors was later shown capable of the same [6].

References

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