MEMRISTOR: THE FOURTH ELECTRICAL COMPONENT

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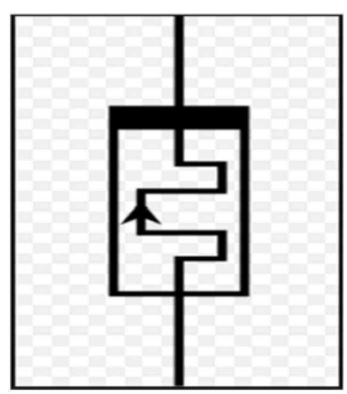
Abstract
As of 2018, there are 3 known and widely accepted passive elements. They are the resistor, inductor and capacitor. The resistor links voltage to current, the inductor links current with flux and the capacitor links charge with voltage. According to the law of symmetry, the 4th passive element was postulated by Leon O Chua in the year 1971. This element is passive and non-linear in nature, linking charge with flux. Due to its elusive nature, it is widely considered to be a missing element. When simulated, it demonstrates an unparalleled competency in limiting or regulating the flow of electrical current in a circuit and it also memorizes the amount of charge that has previously flowed through it at the Nanoscale. It has the potential to revolutionize the semiconductor industry by simplifying existing circuits and giving rise to newer circuits with lower complexity. Devices such as RAM (the most frequent storage method) can be dramatically improved. It can also replace the flash memory with its high-density data storage while increasing retaining capacity of the content it stores for longer periods of time. Memristors also have applications in forefront of research in nonlinear and non-periodic oscillators. These circuits are referred to as Chaos or Chua's Circuit. The Memristor can be used to model Chua's attractor which is one of the types of Chaos circuits.

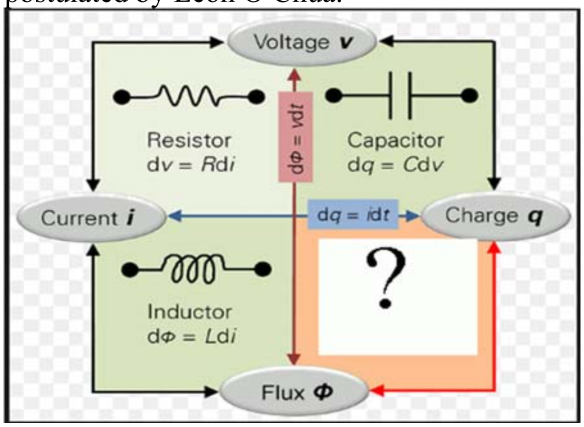
I. INTRODUCTION

The Memristor (short for memory resistor) is a yet quite unknown circuit element, though equally fundamental as resistors, capacitors, and coils. It was predicted from theory arguments nearly 40 years ago, but not realized as a physical component until recently. The Memristor shows many interesting features when describing electrical phenomena, especially at small (molecular or cellular) scales and can in particular be useful for bioimpedance and bioelectricity modelling. It can also give us a richer and much improved conceptual understanding of many such phenomena. Up until today the tools available for circuit modelling have been restricted to the three circuit elements (RLC) as well as the widely used constant phase element (CPE). However, as one element has been missing in our modelling toolbox, many bioelectrical phenomena may have been described incompletely as they are indeed memristive. Such memristive behaviour is not possible to capture within a traditional RLC framework. In this paper we will introduce the Memristor and look at memristive phenomena. The goal is to explain the new Memristor's properties in a simple manner as well as to highlight its importance and relevance..

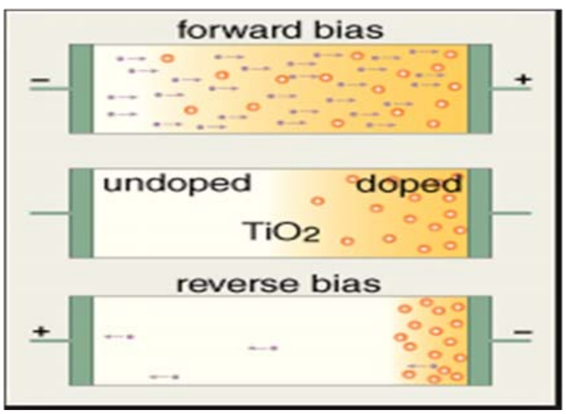


II. THEORY OF MEMRISTORS

Memristor is deduced from memory resistor. It is a passive two terminal device characterized by relating charge q(t) and flux linkage Φ(t). It implies that resistance depends on flow of charge through the circuit. Based on current direction the resistance either increases or decreases. In absence of current flow in the circuit, the resistance retains its values. It means Memristor can remember the current that last flown through it. Basic three passive elements RLC relates electromagnetic quantities like Voltage (v), current(i), charge(q) and flux(Φ). Resistor is defined by a relationship between v and i. Inductor defined by a relationship between Φ and i. Capacitor defined by a relationship between q and v. According to law of symmetry, Memristor forms missing passive element that relates q and Φ which was postulated by Leon O Chua.



III. CONSTRUCTIONS



A physical Memristor comprises a two-terminal device whose resistance depends on the polarity, magnitude, and also span of time of the voltage applied to it. When the voltage is switched off, then the resistance leftovers as it did just already it was turned off. This makes this device as a nonlinear, non-volatile memory device. The above showed two terminal Memristor uses TiO2 (titanium dioxide) as the resistive material. Here TiO2 works better than the other materials like SiO2. When a voltage is germane across the platinum electrodes, oxygen atoms in the material drift towards right or left direction, depending upon the polarity of voltage, which forms the solid thinner or thicker, thus creating a change in its resistance.

IV. EQUATIONS GOVERNING MEMRISTOR CHARACTERISTICS

The Memristor is an electrical instrument that relates charge q with magnetic flux φ. The resistance produced by the Memristor to the stream of current is called Memristance (M). This relationship can be shown as:

$$M = \frac{d\varphi}{dq}$$

Chua generalized the concept above to represent all Memristive systems. The governing equations for these are:

$$V = M(x,t) * i$$

$$\frac{dx}{dt} = f(x,t)$$

These equations resemble a form identical to that of a non-linear version of Ohm's law but they are different. In these equations, the Memristor demonstrates a dependence on a state variable x as shown. This variable is what distinguishes the Memristor from a non-linear resistor.

The variable t adds time dependence to the Memristor model. It models the variance of resistance with charge flowing through the Memristor. For the sake of simplicity, we must now define the Voltage and Current across the Memristor.

$$V(t) = M\big(q(t)\big) * i(t)$$

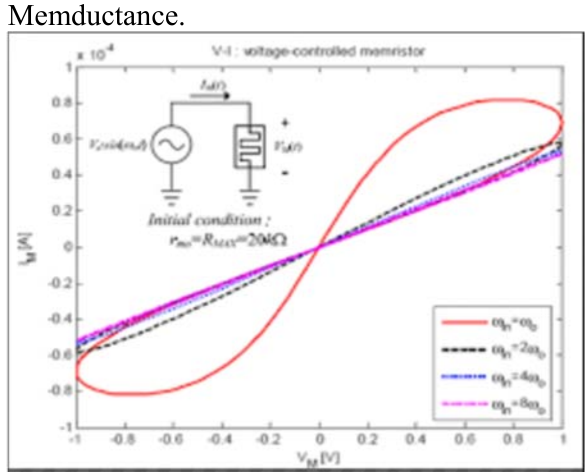
$$i(t) = W\big(\varphi(t)\big) * V(t)$$

$$P(t) = M\big(q(t)\big) * i^2(t)$$

Or

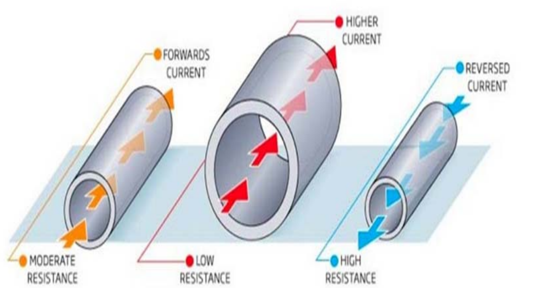
$$P(t) = W\big(q(t)\big) * V^2(t)$$

Where M is Memristance and W is Memductance.



V. Working

For ease of comprehension, let us consider of the Memristor as a cylindrical tube. The charge drifting through the Memristor can be thought to be a liquid flowing through the tube. Initially there is no past input current through Memristor. A positive voltage is given across its terminals and current flows through the Memristor. This can be thought of as water flowing through the tube. When a positive voltage is consecutively applied across its terminals, it causes the diameter of the tube to increase, thereby bringing down the Resistance of the Memristor. Similarly, if a negative voltage were applied across the terminals of the Memristor, a negative current would flow through it. If the voltage were continuously applied, the Resistance of the Memristor would begin to increase until it reaches peak value.



VI. APPLICATIONS

1) **Non Volatile NV RAM -** The Memristor is an electrical instrument that demonstrates memory like behaviour without an uninterrupted supply of power. Sensing the Memristor on a chip theoretically takes little physical area. These characteristics are essential to a having a good Non Volatile Memory (or NV Memory). Digital Memory Application can use one Memristor to collect a single bit of data. DC Voltage can be supplied to store data in the Memristor while AC Voltages can be used to access the data in the Memristor without disturbing its subject-matter. Thus, Memristors grants a inexpensive reach to major amounts of data. 3D Designs have been introduced that offer 1 Petabit per cm^3. While research is in its infancy, the Memristor offers a promising rectification to forthcoming data storage intention.
2) **Logic Design -** These can be applied as a standalone logic gate, or used in hybrid CMOS Memristor circuits. One popular logic application of Memristors is its use in an FPGA as configurable bell-clapper, and in linking the CMOS logic gates. In future Memristors can be employed to do digital logic using implication instead of NAND gates.
3) **Signal Processing -** The signals processed by microwave circuits are typically sinusoidal with very high frequencies with respect to the Memristor characteristics. Consequently, we expect that the Memristor should keep its Memristance at the initial value, which has been setup by some other control circuitry. Therefore, we may possibly replace resistors by Memristors in the traditional designs of microwave circuits. It should be noted that the way of the Memristor modelling in this case is not so much important because our model at such frequency range behaves as a pure linear resistor.
4) **Wilkinson Power Divider -** The Wilkinson power divider a microwave device that inherently comprises a resistor in its realization. The resistance value is critical for the expected operation, so the Memristor might be a promising solution.
5) **Memristors as filters -** The Memristor-based filters have shown a wider rejection band and suppression of the unwanted pass bands at the frequencies that are even multiples of the centre frequency of the desired pass band. By fine tuning the Memristance value, a compromise between attenuation in the pass band and the amount of suppression could be achieved.

Our idea consists in a circuit design in which low voltages are applied to Memristors during their operation as analog circuit elements and high voltages are used to program the Memristor's states.

VII. Future Scope

We are currently working on important areas which are not yet completed and can be regarded as the future work in this field. Some of them are as follows:

1) Investigation of thermal effects on Memristor based RRAM.

2) Study of ballistic transport and quantum mechanical effects on the nanoscale Memristor device.

3) Design a new kind of In-Memory computing platform using Memristor device, which can be used for the next generation Memory with logic (ML) architecture.

4) Design and development of mixed mode programmable analogue circuits using Memristor.

5) Investigation of stochastic and time series analysis of Memristor based RRAM.

6) Development of high performance Memristor using physical synthesis technique.

7) Development of efficient circuits for read and write based on Memristor based RRAM.

8) Modelling and Development of Memristor based 1T1R memory architecture.

9) Design a neuromorphic hardware platform using Memristor.

10) Study the nonlinear dynamics of the Memristor for the cryptographic applications.

VIII. Conclusion

Memristor will benefit developers with low cost and the ability to construct applications through remaining and looking for innovate yet new opportunities. The question is: Will Memristor craft is possible to make extremely integrated devices with fewer parts yet lower power consumption. Memristor would revolutionize the inventory, the technology and embedded systems in terms of applicability. Memristor will change the circuit design in the 21st century as radically as the transistor changed it in the 20th century.

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