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# A review on the Performance of the Fourth Fundamental Bilateral Circuit Element (Memristor) in Different Circuits

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**ABSTRACT**

The present study considers the reviews done on memristor in the recent years, and also investigates three different models of memristor structure including linear, non-linear and the performance of memristor in high-chaos circuits. As the results of the simulation indicate non-linear model has a better performance than linear one. Two distinct features of memristor include low power consumption and its capability to have a memory.
**KEYWORDS:** memristor, high-chaos circuits, structure linear and non-linear

## 1- INTRODUCTION

If we consider three elements of the fundamental bilateral capacitance circuit, inductance and resistance along with the elements forming them, and put them on a vertical axis, it could be seen that capacitance is located between two axes (hubs) including voltage and electric charge, inductance is located between current and flux, and resistance is located between voltage and current. In 1992 Leon Chua suggested a name for the element which is located in this vacancy entitled memristor. These axes (hubs) are shown in Figure 1.

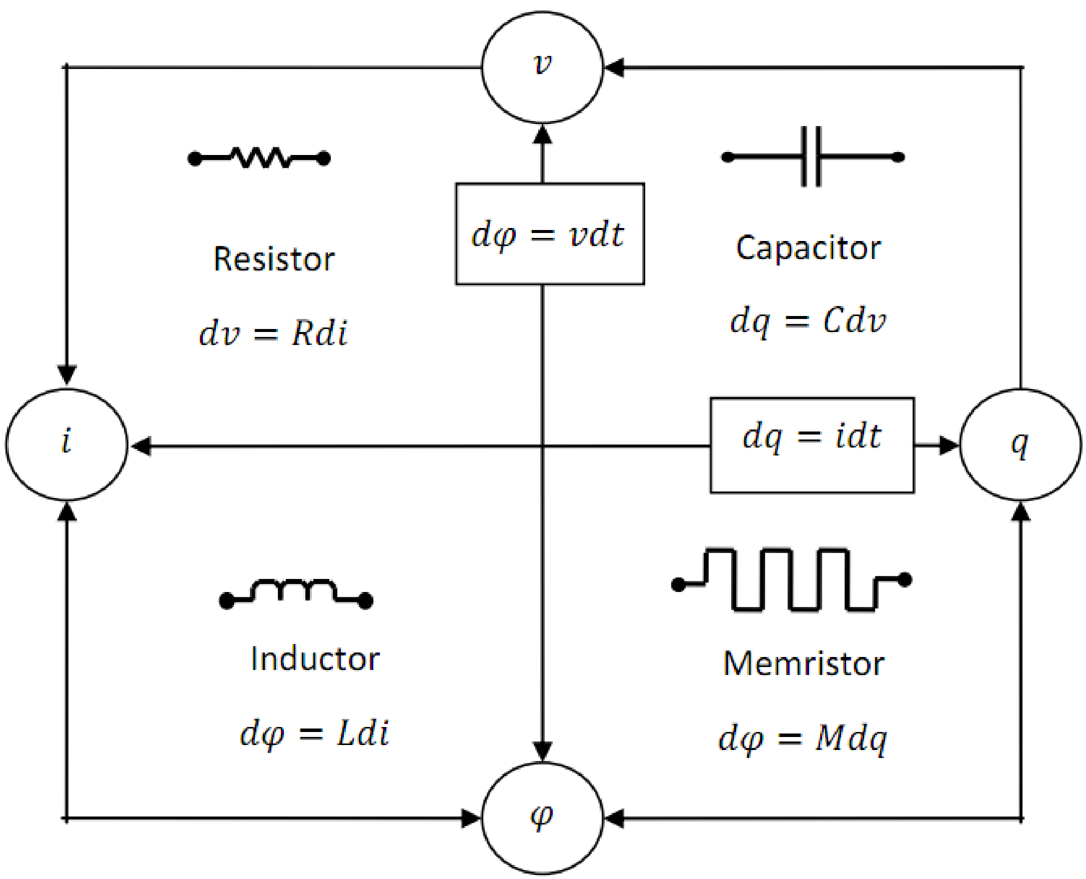


Fig 1: a view of the location of the fundamental bilateral elements among their forming components

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The first memristor which was built in 2008 by Stanley Williams contributed largely to the study and use of this element in circuits. Depending on the memristor structure which is obtained by the ratio of electric charge to magnetic charge, it can be understood that it has both a resistance factor and a storage or memory factor. Memristance establishes a linear relationship between current and voltage until electronic charge does not change, so if electric charge does not change and remains constant, memristance acts same as resistance. If electric load is represented by a function of magnetic flux, when an electrical charge finds its way toward the same way, memristor resistance increases, vice versa. When the applied voltage is stopped, thereby it stops the flow of electric charge, while memristor can remember its last resistance value. When the electric current load is re-established, the resistance in the circuit is the same last value prior to source disconnection. Memristor is similar to a pipe with variable diameter which its diameter increases from one side to another side of pipe, and its diameter decreases in the reverse direction of pipe diameter, and this increase and reduction in pipe diameter leads to the increase and decrease in the flow of fluid inside the pipe, however, when the pipe is closed the same amount of fluid remains in pipe. HP Memristor is a thin layer which is located between two metal layers like a sandwich. As it could be seen in Fig.2, memristor is a very small device which has two parts with high and low resistance. Also, memristor can maintain its mode following discontinuation of the switch. Memristors are widely used in potential and applied applications of digital memory and logic, analog circuits, CMOS and even some applied biomedical programs (STRUKOV,2008).

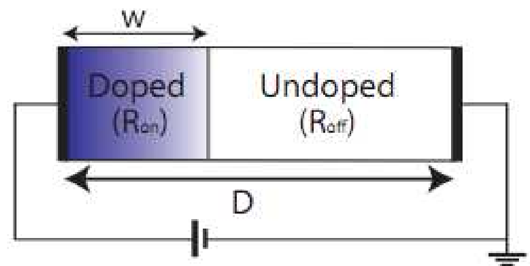



Fig 2: a view of memristor structure

Memristor is also applied in high-chaos circuits because given the non-linear curve which includes an electric and magnetic element (Fig 3) it can have a good performance in high-chaos circuits (Hazem Elgabra.2012).

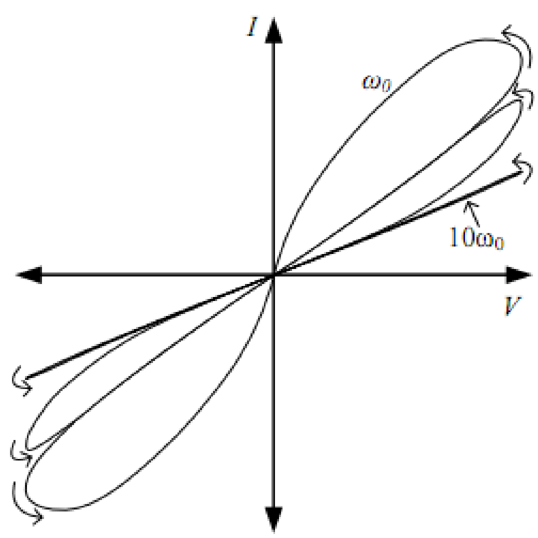



Fig 3: a view of the current, Memo structure voltage

To understand better the performance of memristor in circuits practically, OP-AMP operational amplifier is used. This structure shows the behavior of memristor out of its physical structure.

### 2- The models studied

The present study considers different modes on memristor. In the first, second and third part, linear structure, non-linear structure and the performance of memristor in high-chaos circuits are investigated.

#### a. Memristor linear structure

Memristor is a bipolar structure which shows a storage property with its own ionic and electric bonding link. The resistance depends on current or flux passing through it. Memristor switching depends on how it is biased. To switch on memristor, there is a clear need for a positive bias. Also, to turn it off, a negative bias must be applied.

The mode equations, memristor and Ohm Rule for a memristor are as follows (Hazem Elgabra.2012) :

$$v = R(w.i) \qquad (1)$$

$$\dot{w} = f(w,i) \qquad (2)$$

W is introduced as the memristor mode variable.
The memristor linear equations are as follows:

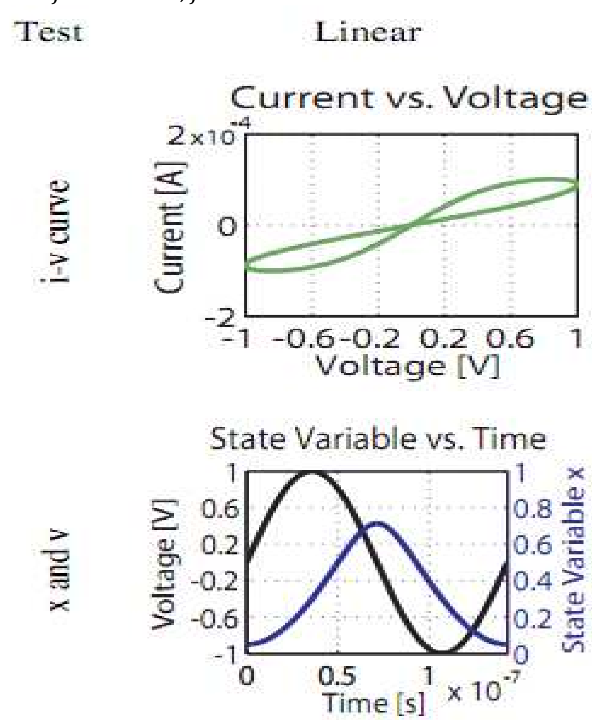
$$v = M(x)i \qquad (3)$$

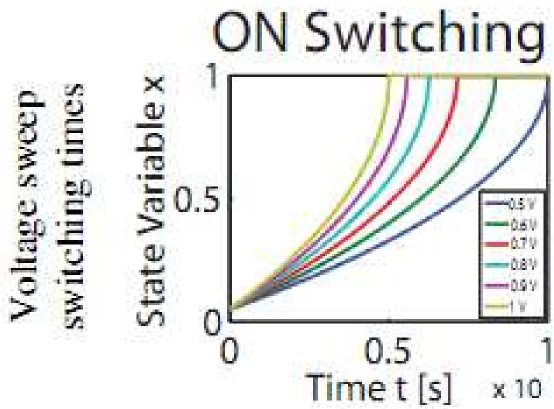
$$M(x) = R_{ON}x + R_{OFF} \qquad (4)$$

$$\dot{x}(i) = \frac{\mu R_{ON}}{D^2} i(t) = ki(t) \qquad (5)$$

$\mu$ is a coefficient which can cause charge and motion in memristor. D is the length of the part, $k$ is the constant value equal to$\frac{\mu R_{ON}}{D^2}$ and $x$ is the mode variable$x = {}^{w}/_{D}$, which indicate the values between on, off and zero parts. As it could be seen in the simulation of this model, the model has some disadvantages including closeness of the mode variable to zero. The results are as follows (PICKETT)

Linear model : $\mu = 145\ e - 9\ fm^2s^{-1}v^{-1}$ , $f = 7MHZ$






The main reason of immediate response is sensitivity to the voltage levels, because the original equation is completely non-linear and it is regarded as a non-linear one.

**b. Memristor non-linear structure**

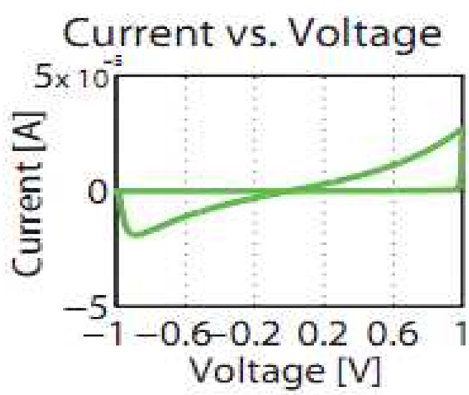
The more complete and sophisticated model for this part is a non-linear model, and the following non-linear equation is obtained by using (5) (YOGESH,2009) .

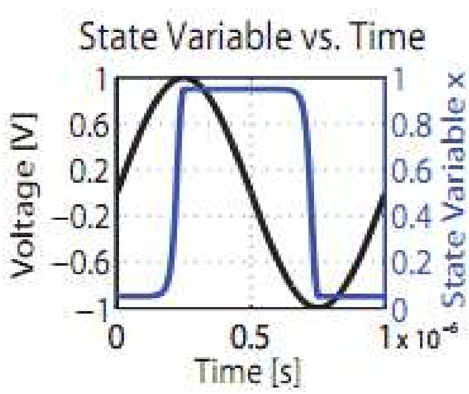
$\dot{x}(t) = ki(t)f(x)$ (6)

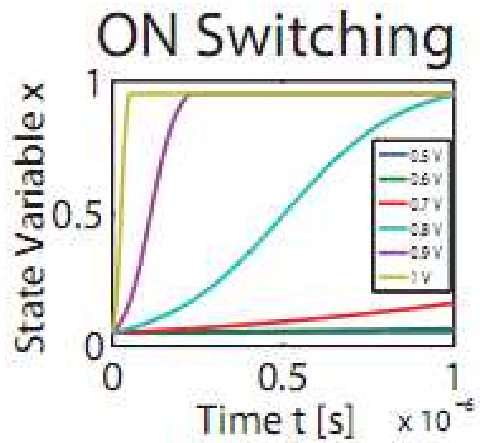
$f(x) = x(1-x)$ (7)

Based on the above equations, the simulation results are as follows:

S=1e-6 , c1=9 , c2=0.01, d1=4, d2=4 , n=4 , a= 17.9 , b=15, $I_{min=0.05}$ ,$I_{\max=0.95}$ , f=1MHZ






Based on the results it could be seen that in the non-linear model, the behavior of the system is more reasonable and flexible. Low voltage level shows the long duration of switching during process, and so it is possible to attribute high level of voltage to the short time of switching. Also, the sharp points on the curve are formed due to oxygen passing through the device.

**c. The performance of memristor in high-chaos circuits**

To investigate the application of the simulator, the simplest high-chaos circuit is tested. As it could be seen in Fig. 4, this circuit is the result of only one passive linear inductance, inactive linear capacitances and a simulator. The simulator is shown as a non-linear memristor for attracting chaos and is well debated (Xuliang, 2013).

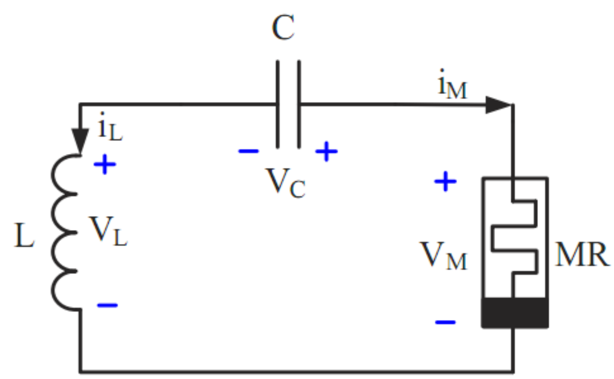



Fig 4: a view of the high-chaos circuit

Dynamic equations are as follows:

$$V_M(t) = M(q).i(t) \quad (8)$$

$$i_c(t) = C\frac{dV_c(t)}{dt} \quad (9)$$

$$V_L(t) = L\frac{di_L(t)}{dt} \quad (10)$$

Fig. 5 shows how to attract the chaos of the circuit in Fig. 4 using Liapanov chaos attraction circuit and sinus input wave with a frequency of 5 kHz.

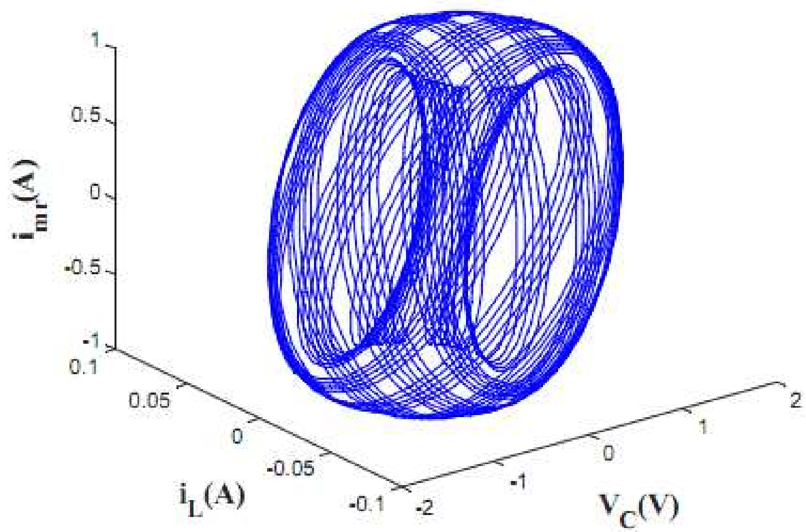



Fig 5: how to attract chaos by using the circuit in the Fig 4

In addition, by solving mathematical equations with several conclusions from dynamic equations and use of Jacobean matrix and Laipanov equations, the behavior of memristor is relatively shown.

The results from the combined dynamic equations are as follows (Muthuswamy,2010) :

$$R(x) = \beta.(x^2 - 1) \qquad (11)$$

$$i_L(t) = C\frac{dV_c(t)}{dt} \qquad (12)$$

$$L\frac{di_L(t)}{dt} = \frac{-V_C(t) - i_L(t).\beta.(x(t)^2 - 1)}{L} \qquad (13)$$

$$\frac{dx(t)}{dt} = -i_L(t) - \alpha.x(t) - i_L(t) \qquad (14)$$

The system Jacobean matrix is as follows:

$$J = \begin{bmatrix} 0 & \frac{1}{C} & 0 \\ \frac{-1}{L} & \frac{-\beta.(x^2-1)}{L} & \frac{-2.\beta.i_L.x}{L} \\ 0 & -x-1 & -\alpha - i_L \end{bmatrix} \qquad (15)$$

Using these equations, the following results are obtained.

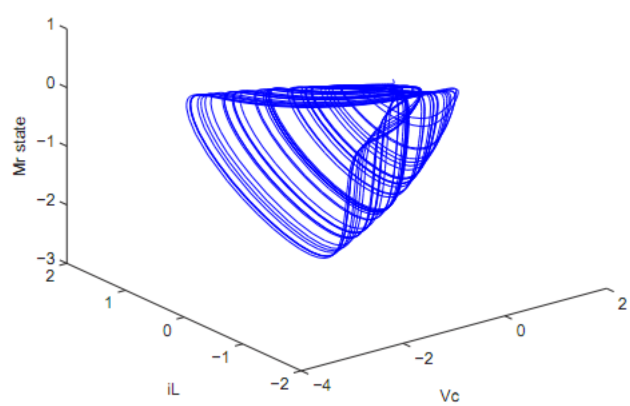



Fig.4. With the Parameters C=1 , L=3 , β=3/2 , α=0.6 .

### 3- Conclusion

The present review study attempts to investigate some behaviors of memristor in different tests, and it could be said that non-linear model has a better performance that linear one. In addition, an analysis of the behavior of memristor in high-chaos circuit and how to attract chaos can result in a better understanding of this device.

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