

# Modeling and Simulation of Memristor using LTspice

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## ABSTRACT

In evolution of memory technology the invention of memristor has colossal impact. It is the memory with resistor as its name indicates its function. The development of memristor as the non-volatile memory device replaces the flash memory and for this reason it is compared to flash memory for the better understanding of the memristor. The only hope for the semiconductor industry is memristor by easier way to increase storage density. These larger storage density and increasing demand for high capacity, high speed and lower priced acts as the force for the research in this field. The performance and the proposing innovation towards the development of the memristor is simulated using the LTspice for new technology in this paper.

Index Terms – Memristor, LTspice

## I. INTRODUCTION

In circuit theory there are three basic two-terminal devices namely-resistor, capacitor, and inductor. These elements are defined by the relation between two of the four fundamental circuit variables- current  $i$ , voltage  $v$ , charge  $q$  and flux  $\phi$ , where the time derivative of charge  $q$  is current  $i$  and according to Faradays laws voltage  $v$  is the time derivative of flux  $\phi$ . The resistor is defined with the relation between the voltage  $v$  and current  $i$  as  $dv = Rdi$ . The capacitor is defined with the relation between the charge  $q$  and voltage  $v$  is expressed as  $dq = Cdv$ . The inductor is defined with the relation between the flux  $\phi$  and current  $i$  as  $d\phi = Ldi$ . The discovery of the existence of the fourth fundamental circuit element came to light in 1971 when Prof. Leon Chua proposed the missing relation between charge  $q$  and the flux  $\phi$  through symmetry in figure 1.1 [1].

Prof. Leon Chua named the element as memristor, which is the short for memory resistor.

The memristor has a memristance  $M$  and the functional relation between flux  $\phi$  and charge  $q$  is given by  $d\phi = Mdq$ . The already known passive two-terminal devices are the basic building blocks of modern electronics and are therefore ubiquitous in circuits. But we know that though some elements store information they eventually decay out. Even if the state of one element changes, the information about the new state would be lost once the power is turned on and wait sometime. This basic point may seem irrelevant but fundamentally this is very crucial. The capacity to store information without the need of a power source would represent a paradigm change.

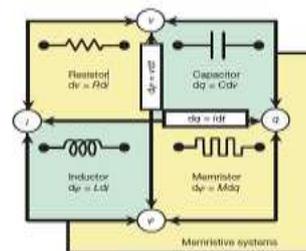


Figure 1. The four fundamental two-terminal circuit elements.

## II. BASIC MEMRISTOR PROPERTIES

The memristor based on a lean film of titanium oxide has been presented as an approximately ideal device. Since then a large deal of efforts has been spent in the research community to study the manufacture and characteristics of memristors. The name Memristor itself indicates its functioning as a resistor having memory of its previous condition. From the circuit-theoretic top of view, the three basic two-terminal circuit elements are defined in terms of a relationship between two of the four fundamental circuit variables. Out of the six possible combinations of these our variables, five have led to well-known relationships. Three other relationships are given, respectively, by the axiomatic definition of the

three classical circuit elements, namely, the resistor, the inductor and the capacitor as stated in Table 1. Only one relationship remains undefined, the relationship between  $\phi$  and  $q$ . It is nothing but the memristance.

Table 1 Fundamental Variables of Electrical Circuits

SL.NO	DEFINITION	EQUATION
1	Voltage( $v$ )	$d\phi = vdt$
2	Current( $i$ )	$dq = idt$
3	Resistance( $R$ )	$dv = Rdi$
4	Capacitance( $C$ )	$dq = Cdv$
5	Inductance( $L$ )	$d\phi = Ldi$
6	Memristance( $M$ )	$d\phi = Mdq$

### III. ORIGIN OF MEMRISTORS

Prof. Leon Chua noted that there are six different mathematical relations connecting pairs of the four fundamental circuit variables current  $i$ , voltage  $v$ , charge  $q$  and flux  $\phi$ . The relation between these variable is deduced from Faradays law of Induction. A resistor is defined by the relationship between voltage  $v$  and current  $I$  ( $dv = Rid$ ), the capacitor is defined by the relationship between charge  $q$  and voltage  $v$  ( $dq = Cdv$ ) and the inductor is defined by the relationship between flux  $\phi$  and current  $i$  ( $d\phi = Ldi$ ). In addition, the current  $i$  is defined as the time derivative of the charge  $q$  and according to Faradays law, the voltage  $v$  is defined as the time derivative of the flux  $\phi$ . This relation is shown in the figure 2 [2].

According to this theory all matter consists of earth, water, air and fire. Each of these elements exhibits two of the four fundamental properties moistness, dryness, coldness and hotness. So depending on the above theory he saw a striking resemblance and predicted the existence of the fourth kind of element and called it memristor. The physical memristor device is essentially an a.c device, or else the d.c electromagnetic fields would give rise to non-negligible zero-order fields.

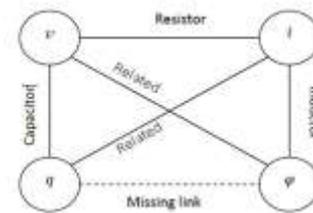


Figure 2. The Relation Between The Circuit Elements.

### IV. DEFINITION OF MEMRISTOR

Memristor, is a contraction of memory resistor because its main function is to remember its history. The memristor is a two-terminal device whose resistance depends on the magnitude and polarity of the voltage applied to it and the length of the time that voltage has been applied. When this voltage is turned off the memristor remembers its most recent resistance until the next time you turn it on. The simple model of this is as shown in figure3 [3]

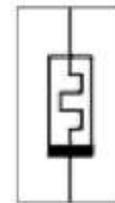


Figure 3. Simple Model of Memristor.

1. Memristor is either said to be a charge controlled or a flux controlled depending upon the relation between the flux  $\phi$  and the charge  $q$  as a function of the other. For a charge controlled memristor the relation between flux and charge is expressed as a function of electric charge  $q$  [2],

$$\phi = f(q) \quad \dots (4.1)$$

By differentiating (4.1)

$$\frac{d\phi}{dt} = \frac{df(q)}{dq} \frac{dq}{dt} \quad \dots (4.2)$$

$$\frac{d\phi}{dt} = v(t) \quad \dots (4.3)$$

$$v(t) = M(q) \cdot i(t) \quad \dots (4.4)$$

$$M(q) = \frac{df(q)}{dq} \quad \dots (4.5)$$

For a flux controlled memristor the relation between flux and charge is expressed as a function of flux linkage  $\phi$  [2],

$$q = f(\phi) \quad \dots (4.6)$$



film is considered to be 10nm and the dopant mobility. The values assumed for  $R_{on} = 100\Omega$ ,  $R_{off} = 16k\Omega$  and the initial resistance  $R_{init} = 11k\Omega$ ,  $D=10N$ ,  $uv=10F$ ,  $p=10$ . The circuit symmetry is shown in figure . The simulation results are shown in figure 10 and figure 11 Parameter details for Transient Non-Linear Domain Analysis  $R_{on}=100\Omega$ ,  $R_{off}=16K\Omega$ ,  $R_{init}=11K\Omega$ ,  $D=10N$ ,  $uv=10F$ ,  $p=10$ , Stop time = 3 seconds, Maximum time step = 3m

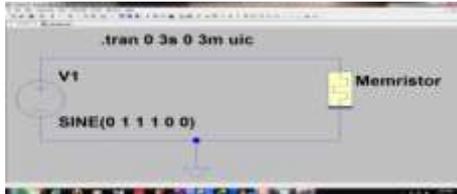
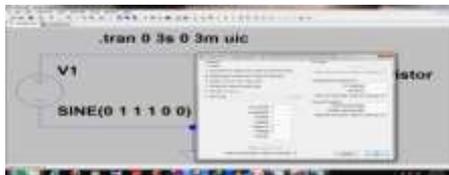


Figure 7 .Memristor Model Circuit



Input source voltage parameter details:

- $R_{on}=100\Omega$ ,  $R_{off}=16K\Omega$ ,  $R_{init}=11K\Omega$ ,  $D=10N$ ,  $uv=10F$ ,  $p=10$ , Sine wave with Amplitude = 1V, Frequency = 1Hz, Time delay = 1 sec.

Figure 8. Input Voltage Applied to the Memristor.

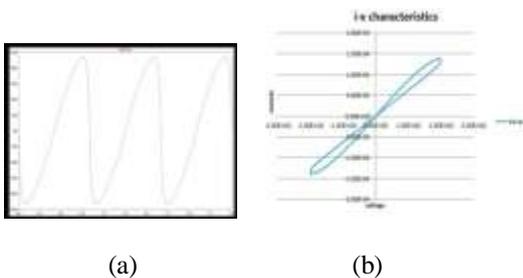


Figure 9 (a) The Current Through Memristor and (b) Current-Verses-Voltage.

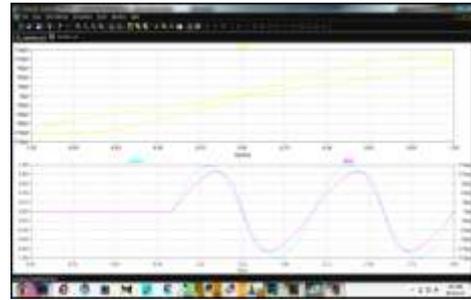
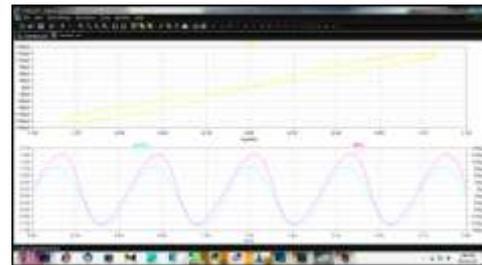


Figure 10. Transient Non-Linear Time Domain Analysis Result of A Memristor Model Using Lt Spice



- $R_{on}=100\Omega$ ,  $R_{off}=16K\Omega$ ,  $R_{init}=11K\Omega$ ,  $D=10N$ ,  $uv=10F$ ,  $p=10$ , Stop time = 3 seconds, maximum time step = 3m, Sine wave with Amplitude = 1V, Frequency = 1Hz, with out any time delay.

Figure 11. Transient Non-Linear Analysis Result(a): F(1 Hz), Td(0), A(1V).

## VIII. CONCLUSION

The impact that the memristor can have on the existing technology is colossal. This report presents the detail study of memristors and also shows some worked out applications. The memristor is modeled in LTSpice using the existing model is proposed and plotted by the use of LTSpice. Memristors has certainly showed a lot of promise and also has the potential to be another milestone in the path of evolution of technology for better. It was rightly said by Prof. Leon Chua that all the engineering text books have to be re-written. The proposed design of NV RAM design is implemented and analyzed using LTSpice software.

## REFERENCES

1. Yasmin Halawani, Baker Mohammad, Dirar Homouz, Mahmoud Al-Qutayri and Hani Saleh "Modeling and Optimization of Memristor and STT-RAM-Based Memory for Low-Power Applications" jun 2015 IEEE ,1063-8210.
2. Mullians.J, 'Memristive minds', in <http://nature.berkeley.edu/Memristor.pdf>.

3. A.Kavehei.S. O, Kim.Y.S and Abbott.D, 'The fourth element: Characteristics, modelling, and electromagnetic theory of the memristor', in [http:// arxiv.org/abs /1002.3210](http://arxiv.org/abs/1002.3210).
4. Benderli.S and Wey.T.A, 'On SPICE macromodelling of TiO2 memristors', in *IET Electronics Lett.*, vol. 45, pp. 377-379, 2009.
5. Biolek.D. B. Z and BiolkovaV, 'Spice model of memristor with nonlinear dopant drift', in *Radioengineering J.*, vol. 18, 2009, pp. 210-214.
6. Biolek.Z, Biolek.D and Biolkova.V, 'SPICE Model of Memristor with Non-linear Dopant Drift', in *Radioengineering*, vol. 18, pp. 210-214, Jun2009.
7. Chua.L, 'Memristor- the missing circuit element', in *IEEE Trans. Circuit Theory*, vol. CT-18, 1971, pp. 507-519.
8. Fano.L.C.R.M. (1960) and Adler.R, 'Electromagnetic fields, energy and forces', in *Proceedings of IEEE Congress on Evolutionary Computation (CEC-2002)*, New York, USA.,
9. Joglekar.Y and Wolf.S, 'The elusive memristor: properties of basic electrical circuits', in *arXiv:0807.3994*, vol. 2, 2009, pp. 1-24.
10. Joglekar.Y.N and Wolf.S.J, 'The Elusive Memristor: Properties of Basic Electrical Circuits', in *European Journal Of Physics*, vol. 30, pp. 661-675, 2009.
11. Kvatinsky.A. K. S, Friedman.E.G and Weiser.U, 'Memristor and related application.'
12. Mahuash.A.C.P.M, 'A memristor spice model for designing memristor circuits.'
13. Strukov.D.B, Snider.G.S, Stewart.D.R and Williams.R.S, 'The Missing Memristor Found', in *Nature*, vol. 453, pp. 83-86, May 2008.
14. Strukov.D.S.D.B, SniderG.S and Williams.R, 'The missing memristor found', in *Nature*, vol. 453, 2008, pp. 80-83.
15. Williams.R, (2008) 'How we found the missing memristor', in *IEEE Spectrum*, vol. 45, , pp. 28-35.