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A New Window Function for Memristor Modeling

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Abstract

Memristor was proposed by Chua in 1971 as a fourth circuit element in addition to the resistor, capacitor and inductor. In 2008, a group of engineers from HP laboratories announced that they were producing a memristor as a physical device. After that, many studies on the memristor were started. Some of these studies are about modeling of the memristor.

One of the widely used methods in modeling of the memristor is a non-linear model in which window functions are used. Here, the window function is a way to take into account of boundary conditions that are not considered in the linear model. Several different window functions are available in the literature that can be used in modeling of the memristor. However, some of them seem to not provide some qualifications that will influence the perfection of the model when examined.

In this study, a new window function is proposed which can be used to model the behavior of the memristor. This function consists of rearranging the Gaussian function with various parameters. These parameters change the form of the window function.

As a result, this new window function satisfies model qualities such as boundary effect, linkage with linear dopant drift model, scalability, flexibility, boundary lock. It also allows the modeling of different memristor constructions through various parameters in the window function.

Keywords: Memristor, Modelling, Non-linear Model, Window Function,

1. INTRODUCTION

The memristor was proposed by Chua in 1971 as the fourth passive circuit element besides the resistor, the capacitor and the inductor [1]. In 2008, a group of scientists from HP laboratories announced that they were producing a memristor as a physical device [2]. After that, the number of studies on the memristor increased rapidly. A correct modeling for the memristor element is very important.

As a result, various methods of modeling the memristor have been proposed in the literature. In 2008, a simple memristor model, called the linear ionic drift model, was proposed by taking into account only the linear drift on the memristive device [2]. But this model has some disadvantages that need to be corrected such as boundary effect. For this reason, it is of great importance to create new memristor models so that the boundary lock, scalability, and nonlinear effects can be met at the same time.

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2. MATERIALS AND METHODS

2.1. Memristor Modeling

2.1.1. Linear Model

The linear model can be expressed by the following equations:

$$v = R(x)i \tag{1}$$

$$R(x) = R_{ON}x + R_{OFF}(1-x) \tag{2}$$

$$x = \frac{w}{D} \tag{3}$$

$$\frac{dx}{dt} = \mu_v \frac{R_{ON}}{D^2} i(t) \tag{4}$$

where R(x) is total resistance, R_{OFF} and R_{ON} are the values of the resistances for $w = 0$ and $w = D$, respectively, x is the normalized width of the doped region, D is total thickness of the memristive device, w is the width of the doped layer, μ_v is the average dopant mobility[2].

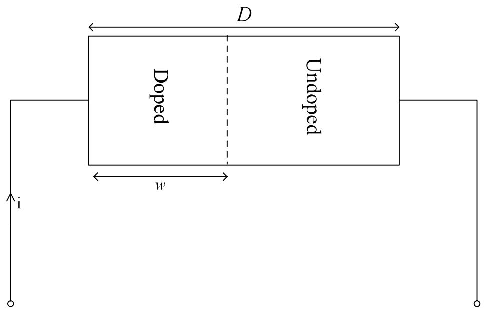

Fig. 1. Memristor model according to [2]

2.1.2. Nonlinear Model and Window Function

The nonlinear model is a more advanced than the linear model. Nonlinear model with window functions has been proposed to overcome the boundary effect problem on the linear model.

$$\frac{dx}{dt} = \mu_v \frac{R_{ON}}{D^2} i(t) f(x) \tag{5}$$

where *f(x)* is a function called window function.

Different window functions have been proposed in the literature to provide a linkage between the linear and nonlinear models [3-6]. In [7], these models were compared according to their ability to meet the required criteria in the modeling.

2.2. New Window Function

In this study, the proposed window functions previously used in the memristor model are examined and a different window function is proposed as

$$f(x) = j \times \left(e^{-\left(\frac{x-0.5}{c}\right)^{2p}} - e^{-\left(\frac{0.5}{c}\right)^{2p}} \right) \tag{6}$$

where j is a scaling parameter, p is a positive integer number, c is a positive real number. Proposed window function provides zero drift at the boundaries.

3. RESULTS AND DISCUSSION

In Fig. 2., the variation of the proposed window function with respect to the x state variable is shown for different p values.

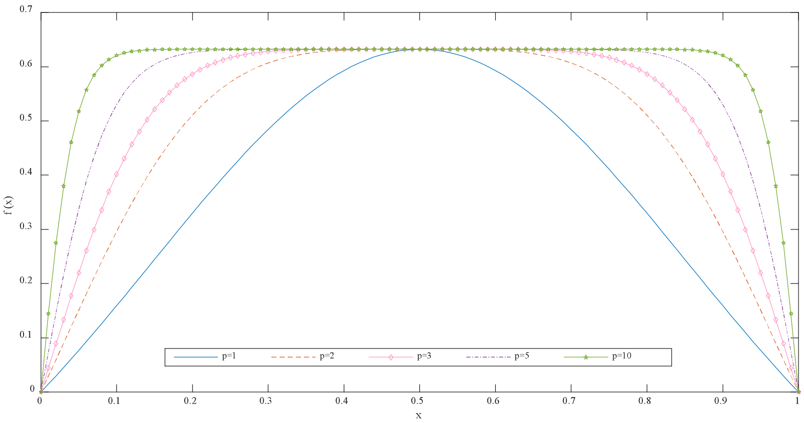

Fig. 2. Change of the proposed window function with x for j = 1, c = 0.5 and different p values

The p parameter plays an important role in the proposed window function. For better performance, it is necessary to select an appropriate p for different applications.

The V-I graph of the memristor model with the proposed window function is given for the p = 1 and p = 10, in Fig. 3.

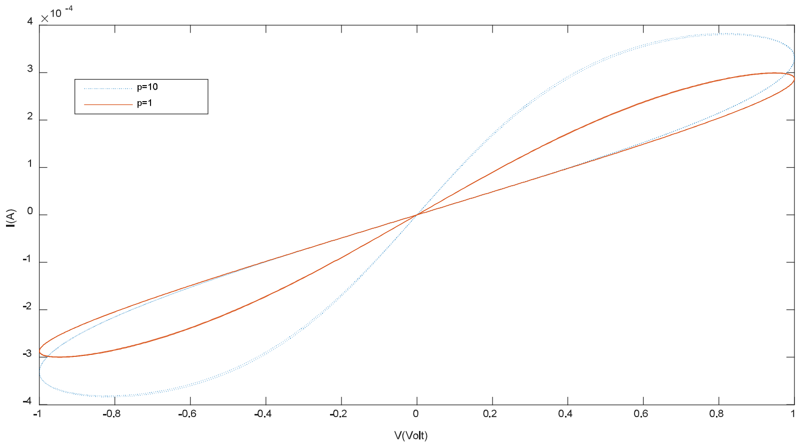

Fig. 3. V-I curves with proposed window function for j = 1, c = 0.5, p=1,10.

The t-x graph of the memristor model with the proposed window function is given for the p = 1 and p = 10, in Fig. 4. t indicates simulation duration.

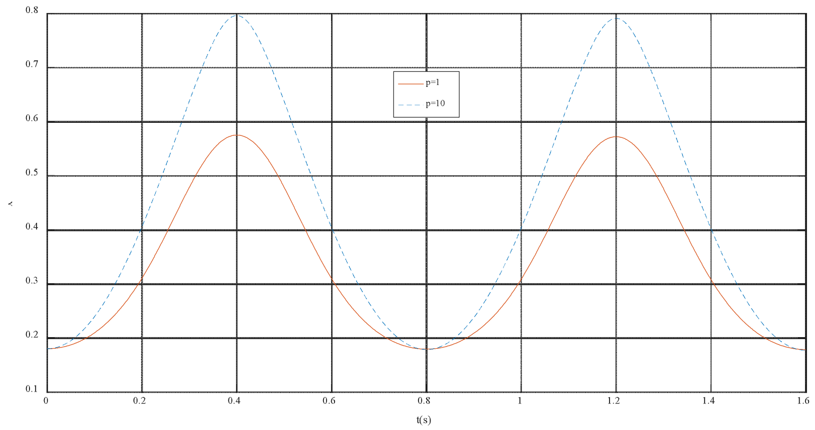

Fig. 4. t-x curves with proposed window function for j = 1, c = 0.5, p=1,10.

In Fig. 5., for the p = 1 and p = 10, the V-R graph of the memristor model with the proposed window function is given. R is the memristor resistance.

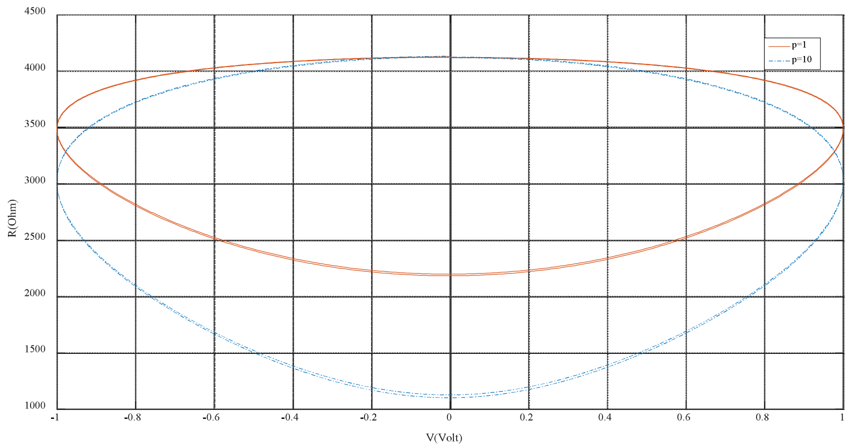

Fig. 5. V-R curves with proposed window function for j = 1, c = 0.5, p=1,10.

In Fig. 3., Fig. 4., and Fig. 5., applied voltage is $V(t) = Vo \sin(2\pi ft)$ where Vo=1V, f =1.25 Hz . R_{ON}=100Ω, R_{OFF}=5kΩ, D=10nm, x_o=0.18, simulation duration is 2/f , simulation step is 1ms and $\mu_v = 10^{-14}\ m^2V^{-1}S^{-1}$.

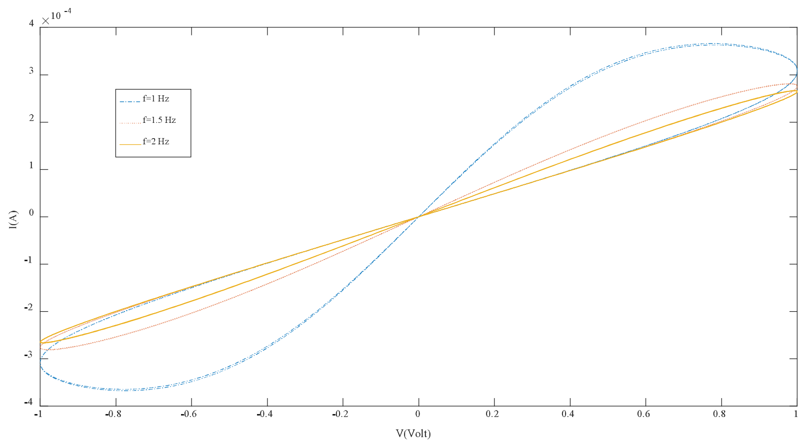

Fig. 6. V-I curves with proposed window function for j = 1, c = 0.5, p=1 and different frequency values.

The V-I graph of the memristor model with the proposed window function is given for f=1, 1.5, 2 Hz , in Fig. 6. In Fig. 6. applied voltage is V(t) =Vo sin(2πft) where Vo=1V. R_{ON}=100Ω, R_{OFF}=5kΩ, D=10nm, x_o=0.18, simulation duration is 2 s, simulation step is 1ms and $\mu_v=10^{-14}\ m^2V^{-1}S^{-1}$.

4. CONCLUSIONS

A memristor is a basic circuit element that obtains its memristive action from the linkage between the electron and ion mobility. Memristor's modeling work is of great importance. Different methods are used for modeling the memristor. The parametric richness of the model used for different memristor applications is important. In this study, a window function for the memristor modeling is established and some application results are shown. The proposed window function is based on three basic parameters. By setting these parameters, modeling results are obtained for different situations.

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