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Research Article

Comparision of models on basic passive circuit components

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Abstract

In this model, the models created by Chua and Wang about high and low order basic passive circuit elements are mentioned and the advantages and disadvantages of these models are commented comparatively. In the Chua model, voltage, current, flux and load are considered as fundamental quantities and these circuit elements are placed with a quadratic method. On the other hand, in the Wang model, a new model is put forward on the grounds that voltage and current are not fundamental quantities, and therefore the quadratic model is not completely correct. According to this model, only flux and load are considered as basic quantities and circuit elements are positioned with a triangular model. However, since there are some deficiencies/errors in the placement of the elements in these two models, we think that both models are not completely correct. Thus, we come to the conclusion that accurately defining the advantages and disadvantages of both models will form an important basis for creating a more accurate model.

Keywords: Memristor, Chua's model, Wang's model

Temel pasif devre elemanları üzerine modellerin karşılaştırılması

Öz

Bu çalışmada, yüksek ve düşük dereceli temel pasif devre elemanları hakkında Chua ve Wang tarafından oluşturulan modellerden bahsedilerek bunların avantajları ve dezavantajlarından mukayeseli olarak bahsedilmektedir. Chua modelinde gerilim, akım, akı ve yük temel büyüklük olarak düşünülerek bu devre elemanları karesel bir metodla yerleştirilmektedir. Buna karşın Wang modelinde ise, gerilim ve akımın temel büyüklük olmadığı ve bundan dolayı karesel modelin tam manasıyla doğru olmadığı gerekçesiyle yeni bir model ortaya konulmaktadır. Bu modele göre, sadece akı ve yük temel büyüklük olarak düşünülmekte ve üçgensel bir model ile devre elemanları konumlandırılmaktadır. Ancak bu iki modelde de elemanların yerleştirilmesinde bazı eksikler/hatalar bulunduğu için her iki modelin tam olarak doğru olmadığını düşünmekteyiz. Böylece her iki modelin avantajları ve dezavantajlarının doğru olarak tanımlanmasıyla daha doğru bir modelin oluşturulmasında önemli bir temel oluşturacağı düşüncesine ulaşmaktayız.

Anahtar Kelimeler: Hafızalı Direnç, Chua modeli, Wang modeli

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1. Introduction

It was thought that the basic circuit elements were now completed, the starting with the invention of the capacitor by Ewald Georg Von Kleist in 1745, and then continuing with the resistor in 1827 by Georg Simon Ohm, and a few years later with the proposal of the coil by Michael Faraday in 1831. However, considering the relations between voltage, current, flux and load, which are accepted as basic quantities by Chua in 1971, it was stated that there should be a circuit element that should establish the relationship between flux and load [1]. After this study [1], researchers began to focus on both this proposed new circuit element and its different derivatives. Afterwards, the relationship between these elements and which basic quantities should be became a matter of debate, and as a result, two separate models were proposed in this field [2,4].

Chua's Model: The first model about circuit elements was proposed by Chua [2]. Chua first created the quadratic model shown in Figure 1 in 1971, the fourth of which he called memristor, and which showed a symmetrical connection between four circuit elements, including the other three basic circuit elements: resistor, capacitor and inductor [1,2]. All elements shown in the same color in Figure 1 are defined as belonging to the same circuit type, that is; They are the forms which are frequency dependent resistors (red), inductors (blue), negative resistors (orange) and capacitors (green) [2]. In this way, when establishing relationships between circuit elements, Chua accepted that there are four different quantities: current, voltage, load and magnetic flux.

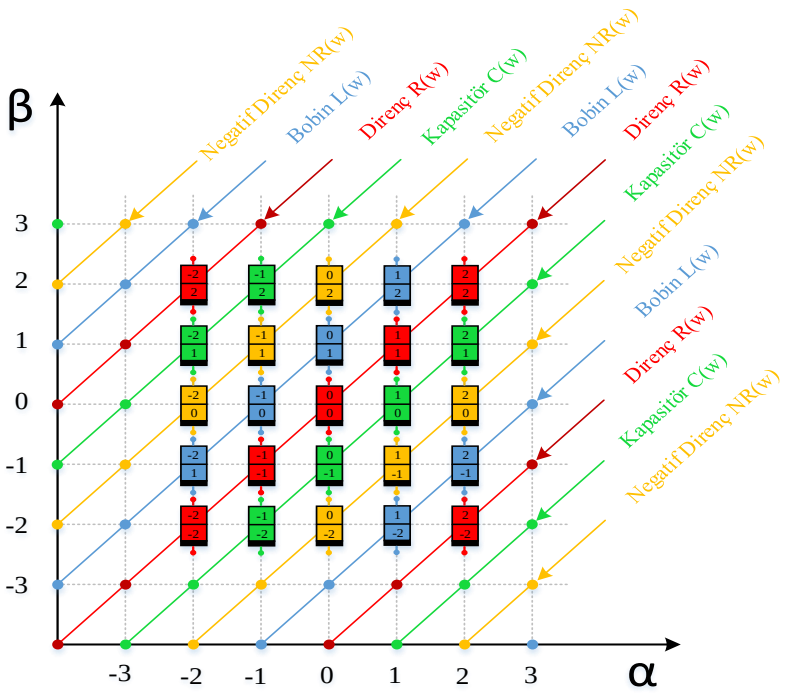

Figure 1. Periodic table of circuit elements developed by Chua [2] in the form of two terminals (α,β).

It is mentioned that in this model, there is a circuit element that establishes a linear connection between each of the four quantities. According to this, a resistor is a circuit element that establishes a relationship between current and voltage, a capacitor between load and voltage, and a coil between flux and current. Chua mentioned this connection in her work in 1971, where he stated that there is no element that provides a connection between the flux and the load, and that this is the memristor, which is a missing circuit element [1,3]. In consequence, Chua created a model by mentioning that the basic elements are not limited to just four, as shown in Figure 1, but are much more.

According to Chua's model, α denotes voltage, β denotes current, and the change along the axis indicates the degree of derivative or integral of current or voltage. In addition, in the model, resistance is considered as [0,0] since it is an element that has a direct relationship with current and voltage. The capacitor is included in the table as [0,-1] since it is the integral of voltage and load (integral of current), and the coil is included in the table as [-1,0] because it establishes the relationship between flux (integral of voltage) and current. Here, the (-) sign denotes the integral and the (+) sign denotes the derivative. For example, according to this model, there is a circuit element that reveals the [-2,+3] relationship, and it provides the relationship between the second-order integral of the current and the third-order derivative of the voltage. As seen in Figure 1 [2], the elements arranged diagonally are of the same type; for example, all of the red colored elements represent the series of elements that show resistor properties, the blue colored elements show coil properties, the green colored elements show capacitor properties, and finally the yellow colored elements represent the series of elements that show negative resistance properties.

Wang's Model: Wang [4], in her Chua model [5], claimed that the Chua model was not correct by explaining some asymmetric and abnormal situations and listed these claims as follows:

a. Unitary Abnormality: While the passive circuit elements resistor, capacitor and coil have their own units such as Ohm, Farad and Henry respectively, a different unit cannot be recommended for the memristor in the Chua model, and the use of ohm as the unit of the memristor gives the impression that this model is incomplete or incorrect [4].

b. Nonlinearity Anomaly: When Chua's model is examined, it can be said that the elements consist of two different groups. One of these groups consists of linear passive circuit elements such as resistors, capacitors and inductors, and the other group consists of non-linear behavior, including the memristor. In this case, the memristor, which is the element in the second group, should show non-linearity. Otherwise, it can be concluded that the memristor should have the same characteristics as a resistor [1,4].

c. *Status of Fundamental Quantities:* Chua model was developed on the basis of two fundamental relations: voltage and current. It is stated that these relations have the equation forms which are $i = dq/dt$ and $v = d\varphi/dt$. However, Wang [4] states that this assumption is completely incomplete or wrong.

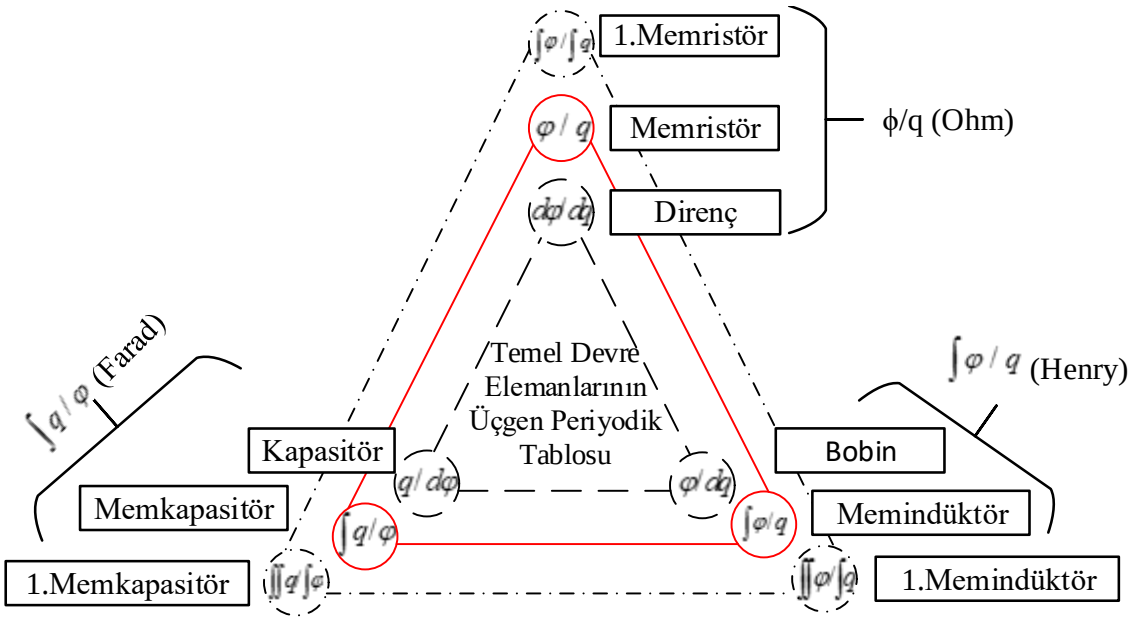

Figure 2. Triangular model developed by Wang for basic circuit elements [4].

d. Presence of Negative Element: In the Chua model [2], there is a negative resistance and the presence of this element causes the inconsistency between active and passive elements. Because negative resistance can be achieved with some active elements.

This model, developed by Wang as an alternative to Chua's model due to the anomalies or deficiencies mentioned by Wang about the Chua model above, is not square but has a triangular format, unlike Chua [4,6]. As a result, it is possible to depict the Wang model, which has two basic quantities and three basic circuit elements, as shown in Figure 2, as schematized by Wang [4].

2. Results and Discussions

In his proposed model, Chua accepted elements such as resistors, capacitors, coils and negative resistors as basic elements, and it is possible to depict the current-voltage curves of these elements as suggested by Chua [2,3], as shown in Figure 3. As seen in Figure 3, the precisely known elements are resistor, capacitor, inductor and memristor. As stated in this figure, the relationship between current and voltage is linear in the resistor, and hysteresis in the oval

memristor, capacitor and inductor. Also, if you pay attention, when the voltage is zero in the resistor and memristor, the current is also zero, and in the capacitor and coil it is different from zero. This means that there is no phase difference in the resistor and memristor and they do not store energy, while there is a phase difference in the capacitor and coil and they store energy [7].

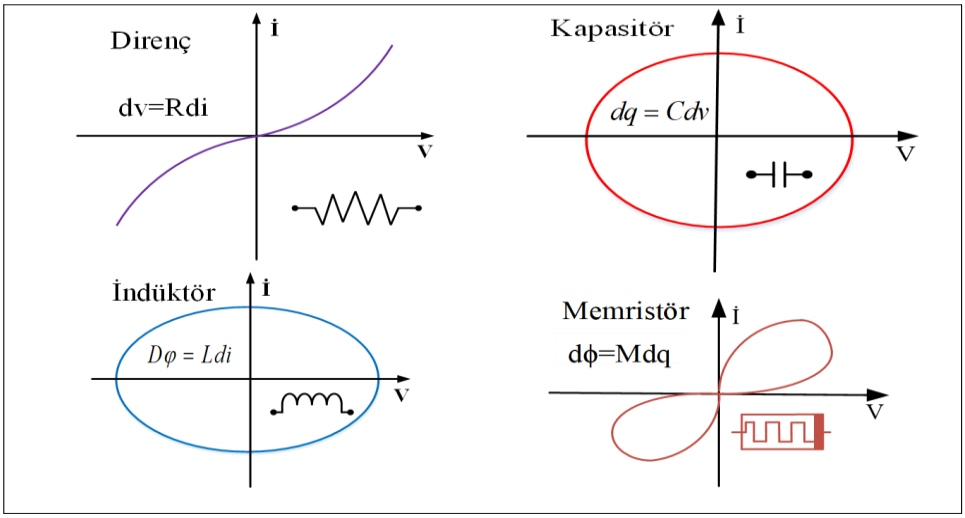

Figure 3. Current-voltage graph of the four basic passive circuit elements, according to Chua's idea.

In addition, since these four elements, the capacitor, inductor and memristor, have frequency-dependent properties, it can be said that these three elements have the ability to store information. When the voltage-current, voltage-load and current-flux curves of memristors, memcapacitors and meminductors, which are considered as memeelements, are examined among themselves, respectively, it can be seen in Figure 3 that the hysteresis curve is obtained. Additionally, when Figure 3 is examined, it can easily be said that the four passive circuit elements are a group or have similar features. It is also possible to observe these changes in different literature studies [8].

Due to the anomalies or deficiencies in the Chua model, the model developed and explained by Wang as an alternative to Chua has a triangular format that not square, unlike the Chua model, as depicted in Figure 2 [4,6]. According to this format, neither resistor, capacitor nor coil are basic circuit elements, but memristor, memcapacitor and memminductor are accepted as basic circuit elements. Another difference of this model from the Chua model is that voltage and current are not accepted as fundamental quantities, and these quantities are only the time derivatives of flux and charge and they are not thought to be separate quantities.

As seen in Figure 2, according to Wang's model, each corner of the triangle represents a different type of basic circuit element. In other words, there are three types of elements as basic circuit elements and the other elements are derivatives of these three elements. For example,

memcapacitor is the basic circuit element and but capacitor or 1st order memcapacitor is a derivative of it.

Table I. Compatibility of the relationship between charge (q) and flux (ϕ) with the new element, according to Wang's idea [4,7].

Relationship between q and ϕ	Compatibility with the new element recipe.
$q-\varphi$	It fits.
$\frac{dq}{dt}-\varphi$	
$q-\frac{d\varphi}{dt}$	
$\frac{dq}{dt}-\frac{d\varphi}{dt}$	It does not fit.

According to Wang's idea [4,9], the fundamental quantities are only charge (q) and flux (ϕ). Therefore, the number of new elements will also decrease as the number of basic sizes decreases. According to Wang's approach, for an element to be a basic circuit element, elements that provide a connection either between the load and flux, or between the derivative or integral of only one of them and itself, can be new elements. As a result, this situation is shown briefly in Table I.

Thus, when these two models are compared, it is possible to say that both models have missing and advantageous parts. In the Chua model, which is the first mentioned model, the basic quantities are accepted as four. At this point, "Are voltage and current a fundamental quantity, or are voltage derived from the derivative of the flux and current from the time derivative of the load, respectively?" It is natural that the question comes to mind. If voltage and current are accepted as quantities, it can be said that the initial assumption of Chua's model is correct and the model proposed by Wang is wrong. However, if voltage and current are not fundamental quantities, then it comes to mind why only charge and flux are fundamental quantities. If it is said that voltage is the time-dependent derivative of flux and current is the time-dependent derivative of the load, then it can be assumed that the flux is the integral of the voltage and the load is the integral of the current. Therefore, this situation cannot be considered as either a completely correct or completely wrong assumption.

Another situation is that negative resistance is present in Chua's theorem but not in Wang's theorem. If the resistor is a new element, the negative resistance is expected to be accepted as a new element. However, this element is present in Chua's table but not in Wang's table.

On the other hand is that Wang did not accept resistor, capacitor and coil as a basic element, and instead memristor, memcapacitor and meminductor were accepted. While a behavior such as resistance exists in almost all elements, it remains a question mark why it is not considered a basic element. The same applies to capacity and coil. Therefore, it will be difficult to accept Wang's theorem as correct in this respect.

Again, three basic elements were accepted by Wang and the other elements were considered as different versions of these three basic elements. This reveals the situation that there will be no new element, which cannot be said to be completely true. In addition, in Wang's theorem, it is assumed that there is no connection between the second order derivative and the first order derivative of an element. In other words, there is always a relationship between the degree of derivative or integral of something and the derivative or integral of that degree.

In Chua's theorem, it has revealed a contradiction the fact that the units of elements such as memristors and memcapacitors are the same as those of resistors and capacitors. Therefore, it can be said that this situation is one of the weakest points of the Chua model.

3. Conclusion

In this study, the Chua and Wang models, which are the two main models proposed so far on passive basic circuit elements, are commented in the terms of circuit elements. These circuit elements, including the basic circuit elements resistor, inductor, capacitor, and the smart resistor (memristor) proposed in their context, are examined in these two models, and the models are compared to each other in terms of circuit elements such as current, voltage and flux.

In the Chua model, current, voltage, flux and charge are considered as fundamental quantities. However, in the Wang model, voltage and current are not fundamental quantities and elements such as flux and charge are considered as fundamental quantities. But, due to our opinion of the fact that there are some deficiencies and errors in the placement of the elements in both models, we conclude that it is not possible to interpret that both models are completely correct in the placement of the elements and their association with each other.

Resultantly, the necessity of new elements increases day by day, but it is of great importance to define and model them mathematically correctly. Predicting the behavior of higher order elements is delayed due to the inadequacy of the presented models. Although both models offered to eliminate this deficiency have disadvantages and advantages, it is important to come up with a new model to overcome this bottleneck. As a result, if a model is to be created, it must first be well defined exactly what the required quantities will be, and the model must be built on it.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Author Contributions

Murat Gülnahar: Designed and wrote the manuscript, and commented conclusions,
Yunus Babacan: carried out interpretation of the figures and models,
Müslüm Gür: interpreted figures.

References

[1] Chua, L. (1971) Memristor—The missing circuit element, IEEE Transactions on Circuit Theory, CT-18 (5), 507–519.

[2] Chua, L. (2003) Nonlinear circuit foundations for nanodevices. Part I: The four-element torus. Proceedings of the IEEE, 91 (11), 1830–1859.

[3] Chua, L. and Kang, S. (1976) Memristive devices and systems, Proceedings of the IEEE, 64, 209–223.

[4] Wang, Frank Z. (2013) A triangular periodic table of elemantary circuit elements. IEEE Transactions on Circuits and Systems, 60(3), 616-623.

[5] Chua, L. (2011) Resistance switching memories are memristors. Applied Physics A: Materials Science & Processing, 102, 765–783.

[6] Wang, F. Z., Helian, N., Wu, S., Lim, M., Guo, Y., and Parker, A. (2010) Delayed switching in memristors and memristive systems. IEEE Electron Device Letter, 31 (7), 755–757.

[7] Gürsul, S., & Hamamci, S. E. (2019) Comparison of different memristor emulators on low-pass filter circuit. In 2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT) IEEE, 1-4.

[8] Barraj, I., Mestiri, H., & Masmoudi, M. (2024) Overview of Memristor-Based Design for Analog Applications. Micromachines, 15(4), 505-508.

[9] Wang, F. Z., Helian, N., Guo, Y., Wu, S., Yang, X., Lim, M. and Rashid, M. (2011) Delayed switching applied to memristor neural networks. Journal of Applied Physics, 111 (7), 07E317–07E317-3.