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Harmonic Generation Analyses of Memristor with Different Barriers and Neuron

Y. Babacan* and F. Kacar

Istanbul University, Dept. of Electrical and Electronic Engineering, Istanbul, Turkey

We investigated the Fourier transform of memristor with various barriers and neuristor. To provide the different barriers we present a simple adaptive model dependent on input signal. We saw that there was no significant change of the harmonics with increasing barriers. Neurons provide an energy and area efficient and could be used in neuromorphic circuits. We used a neuron circuit that can be efficient to provide second and higher harmonics. Neuron circuit generates various spike shapes like regular spike, fast spike, initial bursting, chattering, etc. In this paper we analysed the Fourier transform of the most common spike shapes. The neuron or neuristor can be more efficient to generate second and higher harmonics compared to the other standard circuits.

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1. Introduction

Nonlinear optical devices are potential applications in optical logic gates, optical information storage and laser radiation protection. Hence the researches about this field have increased gradually [1]. Second harmonic generation (SHG) is a nonlinear optical process that is named as "frequency doubling". The propagated light, which lacks a centre of symmetry, produces light at second and higher harmonics of the applied frequency. Such frequency doubling processes are commonly used to generate green light [2].

In 2008 scientists from Hewlett-Packards (HP) discovered memristor [3], this circuit element predicted in 1971 by Chua [4]. The modelling and implementing memristor emulators have been extensively investigated by researchers [5–7]. High harmonic responses have been observed in nonlinear resistors, for this reason memristive systems can be used generating second and high harmonics. The Fourier responses of memristor, memcapacitors, meminductors and memristive bridge circuit have been studied in [8–10]. In this work we present a simple model for single memristor that adjusts barrier height of memristor and the Fourier response of the current through a single memristor with various barrier heights. In addition, we showed the Fourier responses of the output voltage of the cortical neuron circuit with different spikes responses (regular spiking (RS), initial bursting (IB) and chattering (CH)).

2. Fourier transform of memristor with different barriers

We used the Biolek memristor SPICE model [6] to obtain hard switching voltage–current characteristic. The current–voltage relationship is described in Eq. (1):

$$V = [R_{\mathrm{ON}}x + R_{\mathrm{OFF}}(1-x)]\, I. \quad (1)$$

We present a simple theoretical model that depends on input signal that provides us with different barrier height changing single parameter. Memristor with barrier named as the Mott memristor was implemented experimentally in Ref. [11]:

$$i(t)_{\mathrm{Mott}} = i(t)\left[1 - \mathrm{e}^{-(V_{\mathrm{in}}\theta^{10\sigma})}\right]. \quad (2)$$

Here $\sigma = 6$ and θ is chosen as 1.1–1.5–3 for approximately 0.9–0.7–0.35 V barrier voltages, respectively. The applied input voltage–magnitude graphic of (2) is shown in Fig. 1a. We can obtain various barriers changing theta value using MATLAB. Figure 1b shows voltage–current memristor plot with different theta values.

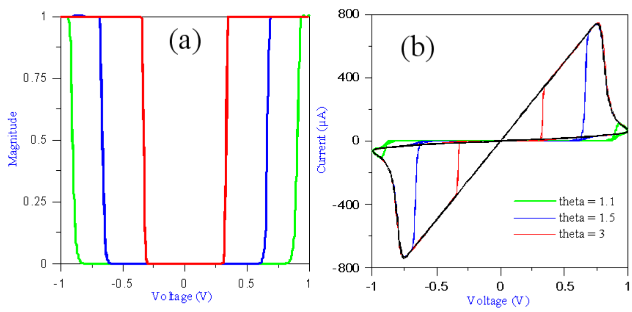

Fig. 1. (a) Barrier function graphics. (b) Hard-switching voltage–current characteristic with different barriers.

We present FT of the memristor current with different barrier of memristor applying sinusoidal input voltage. Joglekar showed those two important results. First, a smooth hysteresis is accompanied by both even and odd harmonics of the applied voltage frequency and the weight of these harmonics decreases monotonically. Second, when the current hysteresis changes to a sharp switching behavior, the FT of the current shows a broad

*corresponding author; e-mail: yunus.babacan@istanbul.edu.tr

non-monotonic structure [10]. Each FT plots were obtained using LTspice circuit simulation program and a significant changes of the harmonics were not observed with increasing barriers as shown in Fig. 2.

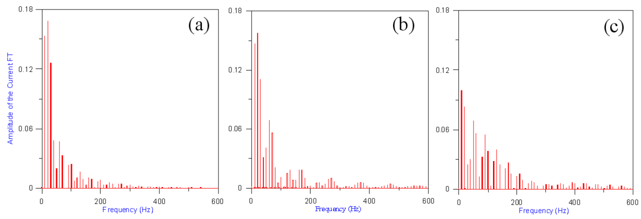

Fig. 2. The amplitude of current Fourier transform (FT): (a) barrier height is zero, (b) barrier height is 0.35 V — $\theta = 3$, (c) barrier height is 0.7 V — $\theta = 1.5$.

3. Fourier transform of neuron circuit with various spikes

We used a single neuron circuit (or neuristor) that can generate various spikes. RS, fast spiking (FS), CH and IB are the most well-known spikes generated by neurons. In this chapter we analysed the FT of RS, IB and CH generated by neuron circuit.

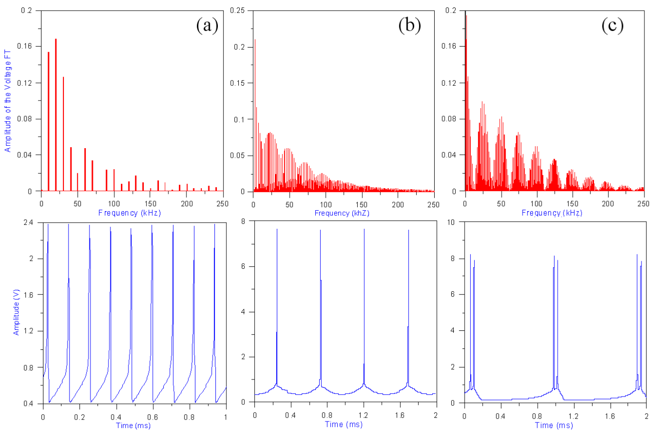

Fig. 3. (a) RS voltage and its FT, (b) IB voltage and its FT, (c) CH voltage and its FT.

The Fourier transform of the all spikes is shown in Fig. 3. FT response of regular spiking is similar to FT of memristor. But other FT responses of both IB and CH have second and higher harmonics. Especially FT of CH spiking of the neuron has higher harmonics.

4. Conclusion

In conclusion, we showed Fourier response of both memristor with different barriers and neuron circuit. We present simple mathematical model dependent on input voltage to adjust barrier height. Diode bridge circuits are used to generate second and higher harmonics. Recently memristive bridge circuit suggested obtaining the harmonics [12]. We have demonstrated the potential of neuron circuits or neuristors to generate second and higher harmonics. Finally, neuron circuits or neuristors can be efficient to provide second and higher harmonics instead of the diodes or memristive circuits.

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