Biología + electrónica: ¿es posible replicarnos?

Biology + electronics: can we replicate ourselves?

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RESUMEN

La fascinación por replicar el funcionamiento del cuerpo humano, existe desde las primeras observaciones de Prometeo, Thévenot y Tremblay, es por ello, que el desarrollo de herramientas para tratar lesiones y enfermedades ha sido de los primeros legados de la humanidad. En la actualidad, los desarrollos robóticos se han centrado principalmente en la reproducción de los movimientos propios de un ser vivo, por ejemplo la locomoción, sin embargo, estos movimientos no han podido reproducirse en su totalidad debido a que aún no logramos descifrar los circuitos neuronales que conforman al Sistema Nervioso Central (SNC) y que gobiernan nuestros movimientos. El SNC está formado por células llamadas neuronas. Las neuronas biológicas tienen un comportamiento bastante complejo que ha sido estudiado durante cientos de años, sin embargo, lejos queda aún el día en que podamos entender en su totalidad su funcionamiento y por ende el del SNC. Con base a lo anterior surge la tarea de crear modelos del comportamiento neuronal y es por ello que en el presente trabajo, se propone una síntesis circuital que emplea componentes electrónicos básicos y es capaz de replicar un potencial de acción (biopotencial).

PALABRAS CLAVE: neurona artificial, biopotencial, biología + electrónica

Abstract

The fascination for replicating the workings of the human body, exists since the first observations of Prometheus, Thévenot and Tremblay, that is why, the development of tools to treat injuries and illnesses has been the first legacies of humanity. Currently, robotic developments have mainly focused on the reproduction of movements of a living

being, for example the locomotion, however, these movements may not have able to reproduced entirely since we cannot even decipher the neural circuits that make up the Central Nervous System (CNS), which govern our movements. The CNS is composed of cells called neurons. Biological neurons behave quite complex, it has been studied for hundreds of years, however, the day in which we can understand entirely its operation is still far away. Based on the foregoing, it arises the task of creating models of neuronal behavior and is therefore proposed in the present work, a circuit synthesis that uses basic electronic components and is capable to replicate an action potential (biopotential).

Key Words: artificial neuron, biopotential, biology + electronics

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Introduction

The most common causes of disability and death are heart diseases, lungs, liver, kidneys and pancreas, which are treated by transplantation of organs (Cascalho and Platt J, 2005; Cascalho and Platt J., 2006). However, the shortage of donors is compounded year after year as the population ages and cases of organ failure increases. The fascination with the ability to regenerate tissues and organs, has existed since the first observations of Prometheus, Thévenot, and Tremblay (Badylaka and Neremb, 2010), the development of tools to treat injuries and illnesses has been one of the first legacies of humanity, such is the case of Leonardo da Vinci, who proposed that some of the concepts of engineering may apply in the human body (Badylaka and Neremb 2010). In 1958, an air force medic of the United States of North America, Jack Steele first proposed the term: bionics (also known as Biomimetics) (Badylaka and Neremb, 2010), which is currently used to designate the application of engineering principles to replace or boost physiological functions inherent in tissues or organs, using electronic components, mechanical or electromechanical (Badylaka and Neremb 2010). From the beginning the construction of Bionic objects was proposed to help humans injured or who had lost a limb. Advances in materials science, electrical engineering, biochemistry, improvement in biomaterials,

robotics, tissue engineering and the applied calculus, have led to important advances in medical bionics. Based on the obtained results, medical Bionics is now an important component for modern biotechnological health treatments. The most common examples of Bionic therapies are: mechanical prostheses for limbs (Ashrafian', Darzab and Athanasiou, 2010), artificial muscles such as the heart, analysis of the neuronal circuits (Manjarrez, Hernández-Paxtian, and Khon, 2005) for its implementation (López, 2009; Hernandez, Jimenez and Ramirez, 2011), the retina and (Weiland and Humayun, 2008), cochlear implants artificial liver (Alastair and Neuberger, 2002). Occasionally, some of these bionic aid not only act as "tissue replacements" but outperform their human counterparts dynamic as in the case of the athlete Oscar Pistorius, who has no legs, but can outperform other sprinters who have a " Normal body "to use their leg prosthesis made of carbon fiber (Camporesi, 2008); Miodownik, 2007), in this sense, scientists from different disciplines are interested in building biological substitutes and / or artificial to restore and maintain the normal function of diseased tissues (Atala, 2008). the goal is the research and application of engineering principles to problems in biology and modification of organisms and biological processes for useful purposes.

Replicate the functioning of our body has led us to make robotic developments have focused primarily on the reproduction of the movements of a living being, such as locomotion, however, these movements have failed to reproduce in full because we can not decipher the neural circuits that make up the central nervous system (CNS) and govern our movements.

The history of artificial neural networks begin with the Aragonese scientist Santiago Ramon y Cajal, discoverer of CNS neuronal structure (Martin del Brio and Sanz, 1992). Ramon y Cajal in 1888 showed that the CNS was composed of a network of individual cells, neurons, widely interconnected (Ramon y Cajal, 1901). But not only he observed through a microscope small empty spaces between some neurons of others, but also established information flows in the neuron from the dendrites to the axon through the soma (Figure 1) (Kandel, Schwartz, and Jessell, 2001). The discovery of Ramon y Cajal was basic to the development of neuroscience in the twentieth century, at the time caused a

stir in the way of understanding the SNC, which was given the Nobel Prize in medicine in 1906. Today the work of Ramon y Cajal, texture, continues to be published for the scientific community (Martin del Brio and Sanz, 1992).

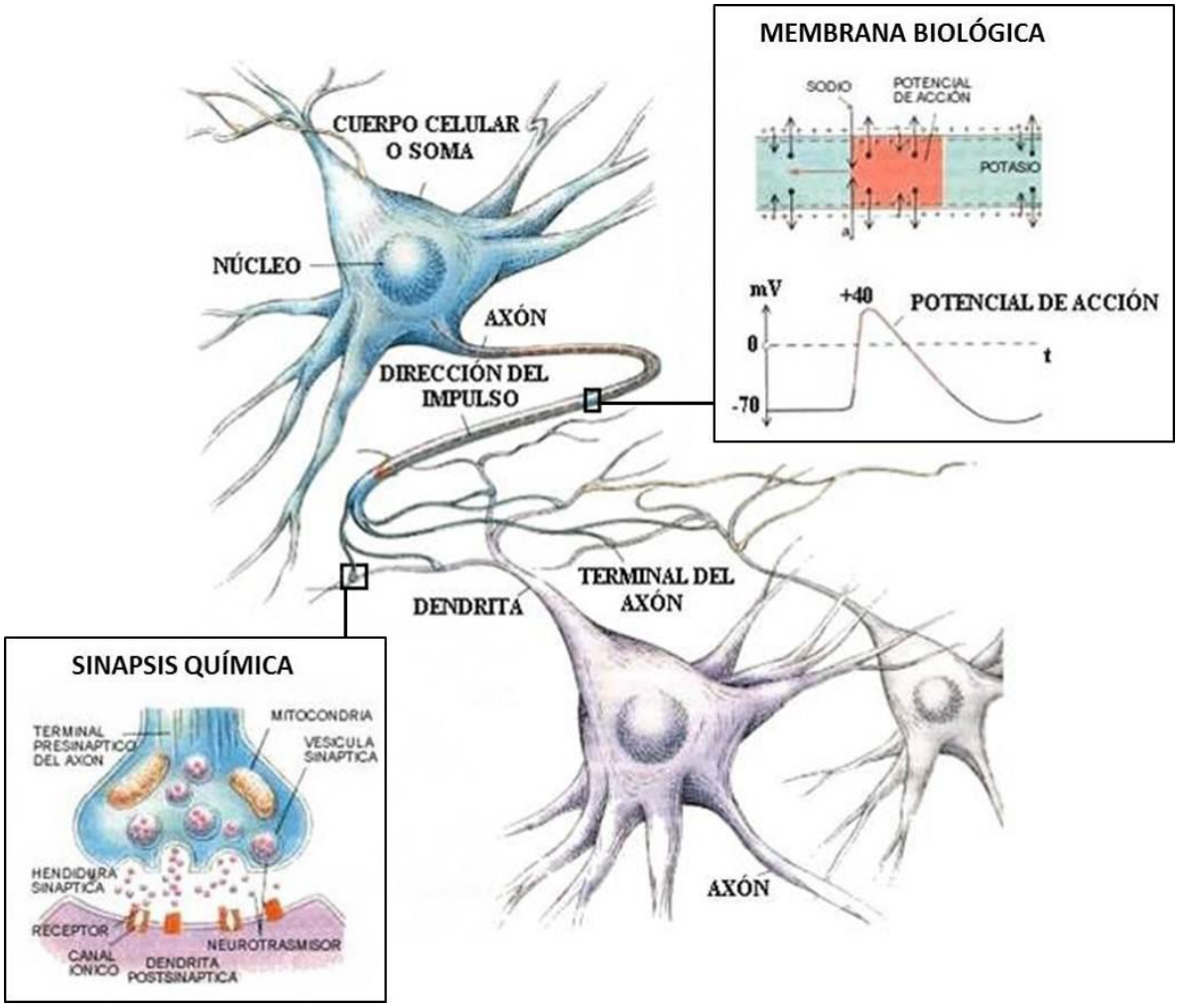


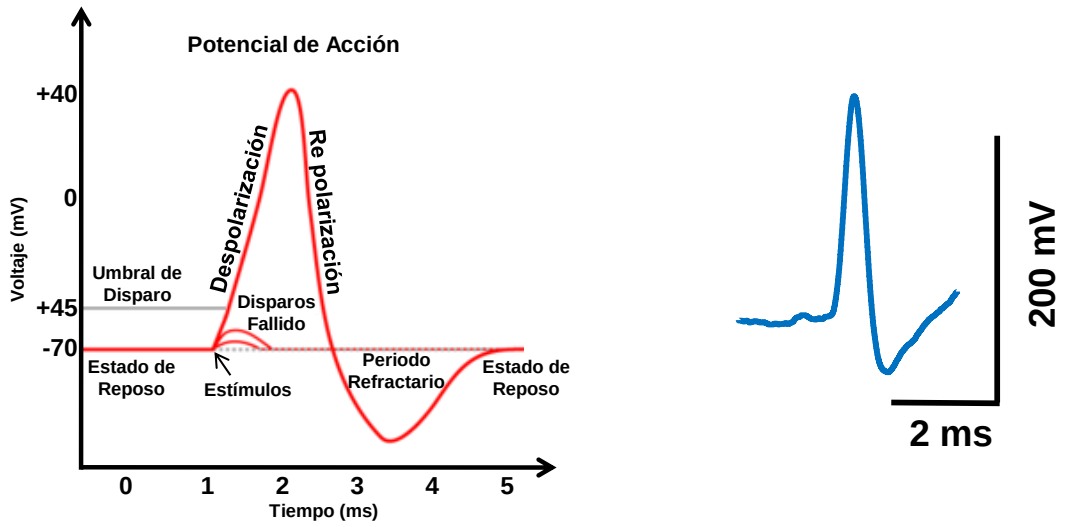
Figure 1. Biological Neuron. Structure of a typical biological neuron synapses and nerve signal generation.

From a functional standpoint, the neurons are simple information processors (Martin del Brio and Sanz, 1992). Like any system of this type, they have a channel input, dendrites, an organ of calculation, the soma, and a channel output, the axon (Figure 1). The junction between two neurons called synapses. In the most common type of synapse there is no physical contact between neurons, but these remain separated by a small gap of about 0.2

microns. In relation to the synapse, there is talk of presynaptic neuron (which sends signals) and postsynaptic (the received signal). Synapses are directional, that is, information flows in one direction (Figure 1) (Kandel, Schwartz, and Jessell, 2001; Stratton, 1984). Nerve signals can be transmitted electrically or chemically. Chemical transmission prevails outside the neuron, while electrical do inside. Chemical transmission is based on the exchange of neurotransmitters, whereas uses electrical discharges occurring in the cell body, and which propagate down the axon (Kandel, Schwartz, and Jessell, 2001; Stratton, 1984).

The phenomenon of the generation of the nerve signal is determined by neuronal membrane and ions present on either side of it (Figure 1). At rest the protoplasm of the neuron remains negatively charged in relation to the external environment, having therebetween a potential difference of approximately -70 mV (Kandel, Schwartz, and Jessell, 2001; Stratton, 1984).

The membrane acts as a capacitor, which is charged by receiving currents due to ionic species present, containing selective ion channels ion type, some are passive (simple consist pores of the membrane) and other assets (only open pores under certain circumstances). In essence, the major ionic species that determine much of the generation and propagation of nerve impulses, are Na +, K + and Ca2 + (Kandel, Schwartz, and Jessell, 2001). If the neuron has received a considerable amount of stimuli, its voltage level reaches or neuronal potential -45 mV (trigger threshold) then abruptly open Na + channels, allowing passage of this ion into the cell, thereby leading the abrupt depolarization of the neuron, passing from a resting potential of -70 mV to +40 mV potential, this process is the generation of an action potential, also called biopotential, so that the spread along the axon results in the electrical transmission of the nerve signal (Kandel, Schwartz, and Jessell, 2001; Stratton, 1984). After being brought an action potential, the neuron undergoes a refractory period, during which you can not generate a new biopotential (Kandel, Schwartz, and Jessell, 2001). An important fact is that the pulse thus generated is "digital", in the sense that there is or there is no pulse (Martin del Brio and Sanz, 1992; Hernández, 1999).



(a) **(b)**

Figure 2. biopotential. (a) voltage levels that make up an action potential or biopotential. Modified (Kandel, Schwartz, and Jessell, 2001). (b) biopotential obtained in response to a motor neuron (a cat) to stimulation. Taken from (Hernandez, 2006).

In this paper the results of the circuital synthesis of a biopotential, ie the design and implementation of an electronic circuit, artificial neuron, capable of playing an action potential (Figure 2) is proposed.

MATERIALS AND METHODS.

Material and Equipment.

3 Operational Amplifiers TL081CN.

3 10uF electrolytic capacitors.

3 100Ω resistors.

1 Resistor 220 Ω.

2 10 k resistors.

Resistors 33 KQ 2 ..

breadboard

oscilloscope

Source voltage of +/- 15V

Methodology.

In Figure 3, the methodology used in the synthesis process detailed circuital.

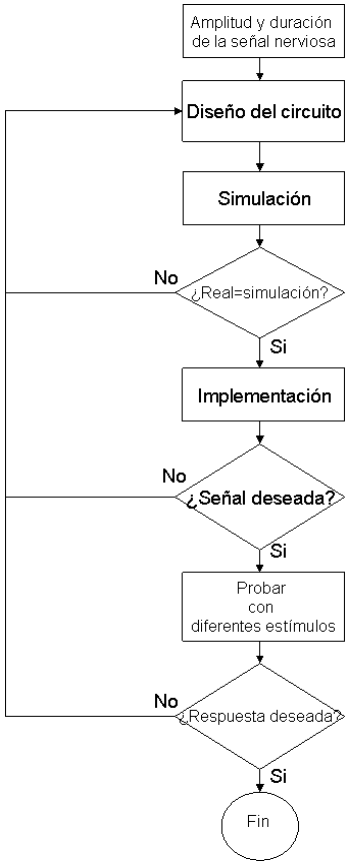


Figure 3. Methodology. Block diagram of the proposed methodology. (Lopez, 2009).

According to (Hopfield and Tank, 1984; Hernandez, 1999) the electronic components used in implementing artificial neurons are: capacitors (representing the biological membrane), resistors (representing ion channels) and operational amplifiers (representing the behavior soma). The electronic circuit design proposed to implement an artificial neuron and this generates a biopotential comprises two stages (Figure 4): a step in which a sinusoidal

signal, which call generation step and a conditioning step is generated which objective is to adapt the signal to achieve the characteristics that define the biopotential (Figure 2 (a)).

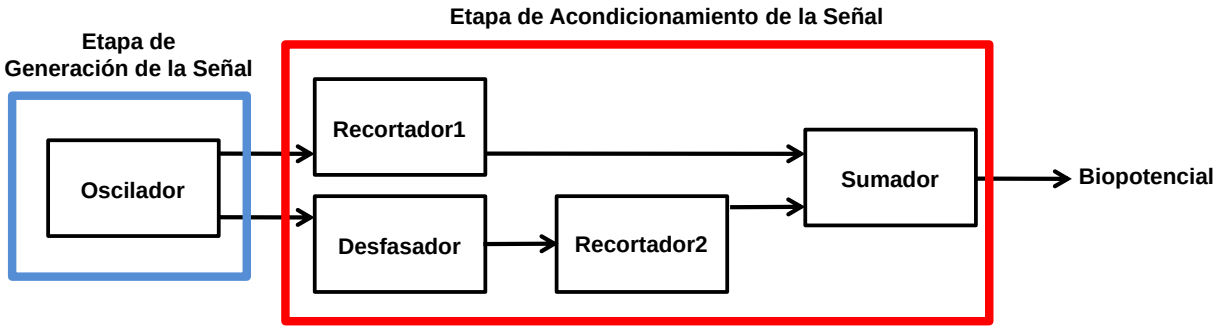


Figure 4. Block diagram. The steps proposed in the design of an artificial neuron and their functional blocks shown. Taken Hernandez, Jimenez and Ramirez, 2011.

In the sections described below, the results obtained by simulating the proposed circuits, for this purpose the use LTspice simulator are presented.

Phase signal generation.

To generate the sine wave use a Wein Bridge (Figure 5) oscillator circuit, because this configuration can generate a signal of low distortion and stable amplitude. The oscillation frequency depends on the proposed capacitors (C1 and C2) and resistors (R1 and R2) values, which are related as shown in Equation (1). The gain of the circuit is obtained from the feedback resistors R3 and R4, a relationship that provides sufficient gain is R4 R3 = 2 * [7].

$$f_0 = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}} \qquad (1)$$

Stage Signal Conditioning.

As shown in Figures 1 and 2 (a), an biopotential it is formed by different voltage levels, to artificially replicate at this stage a phase shifter circuit and two Rememberers circuit is

used, the latter constructed from operational amplifiers and Finally an adder circuit (Figure 5).

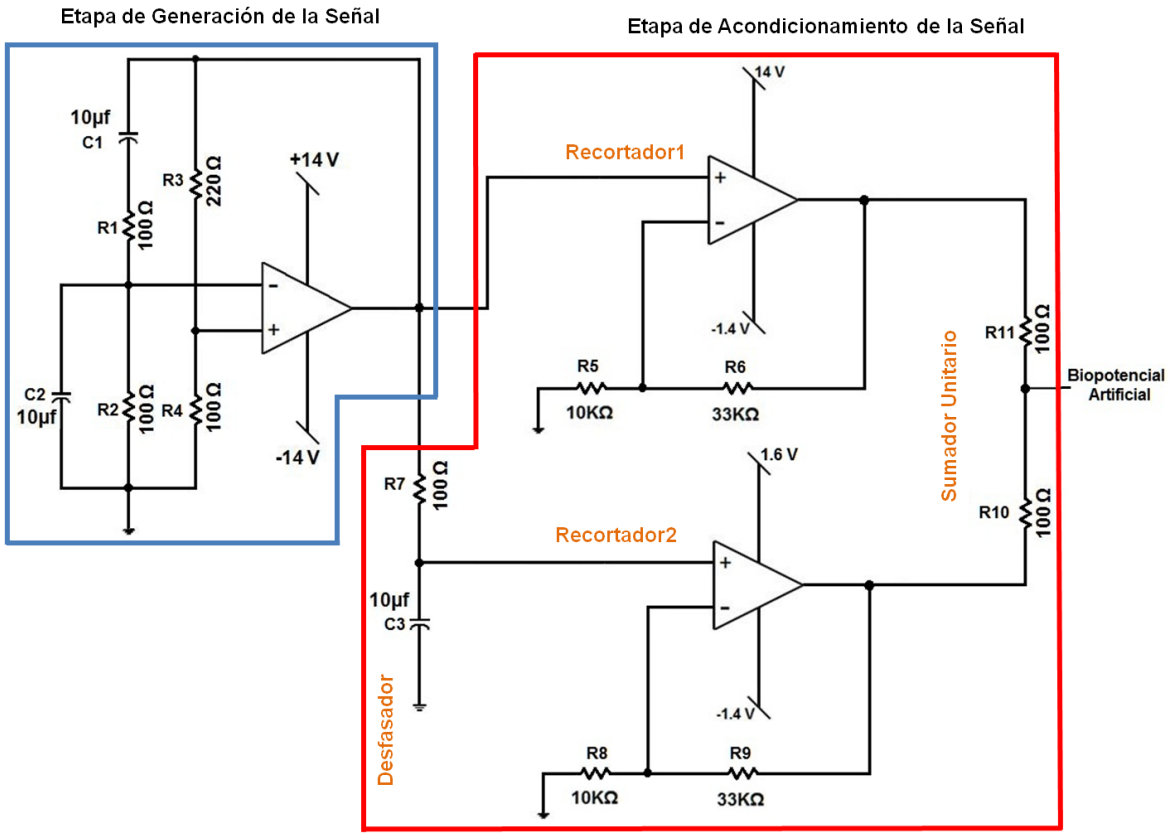


Figure 5. Artificial Neuron. Stage for signal generation, is designed to operate at an oscillation frequency of 160Hz and β 2.2. Clipping circuits for the β is 3.3. Taken Hernandez, Jimenez and Ramirez, 2011.

The function block Recortador1 consists is generated corresponding to the dwell time biopotential voltage, that is, when the neuron is around -70 mV, to accomplish the amplifier is not fed symmetrically, because of this, the amplifier is saturated and the input signal is clipped, Figure 6 (Boylestad and Nashelsky, 1989; Coughlin and Driscoll, 1999).

To play the effect of depolarization of biopotential, this is when the neuron goes from -70 mV to + 40mV (Figure 2 (a)) in the signal conditioning circuit a common phase shifter is

used. Said circuit is a resistive arrangement - capacitive in series (Figure 5). The signal obtained has the same frequency as the original signal but with a time lag determined by the time constant of the RC series circuit. For this case, the proposed values are such that = 1 ms, whereas the output voltage relative to input ratio stored ½, Figure 6 (Boylestad and Nashelsky, 1989; Coughlin and Driscoll, 1999).

The offset signal is manipulated to form part of biopotential corresponding to repolarization (Figure 2 (A)), this operation will be conducted by recortador2 block. Note that voltage levels that constitute the biopotential separately generated, the next step is to bring these potential, this will use a unitary adder. A unitary adder is a stage in which the phase shifted signal (obtained from phase shifter) and clipped (obtained from Recortador2) and the clipped signal (obtained from Recortador1) are introduced and combined in a very simple way. An adder unit consists of two resistors in series which come both signals, Figure 5. When performing circuit analysis unit adder can see that, if R1 = R2 then: $\mathrm{Vsalida} = \mathrm{V1} + \mathrm{V2}$.

The reconstruction process neuronal potential, artificial biopotential action can be seen in Figure 6.

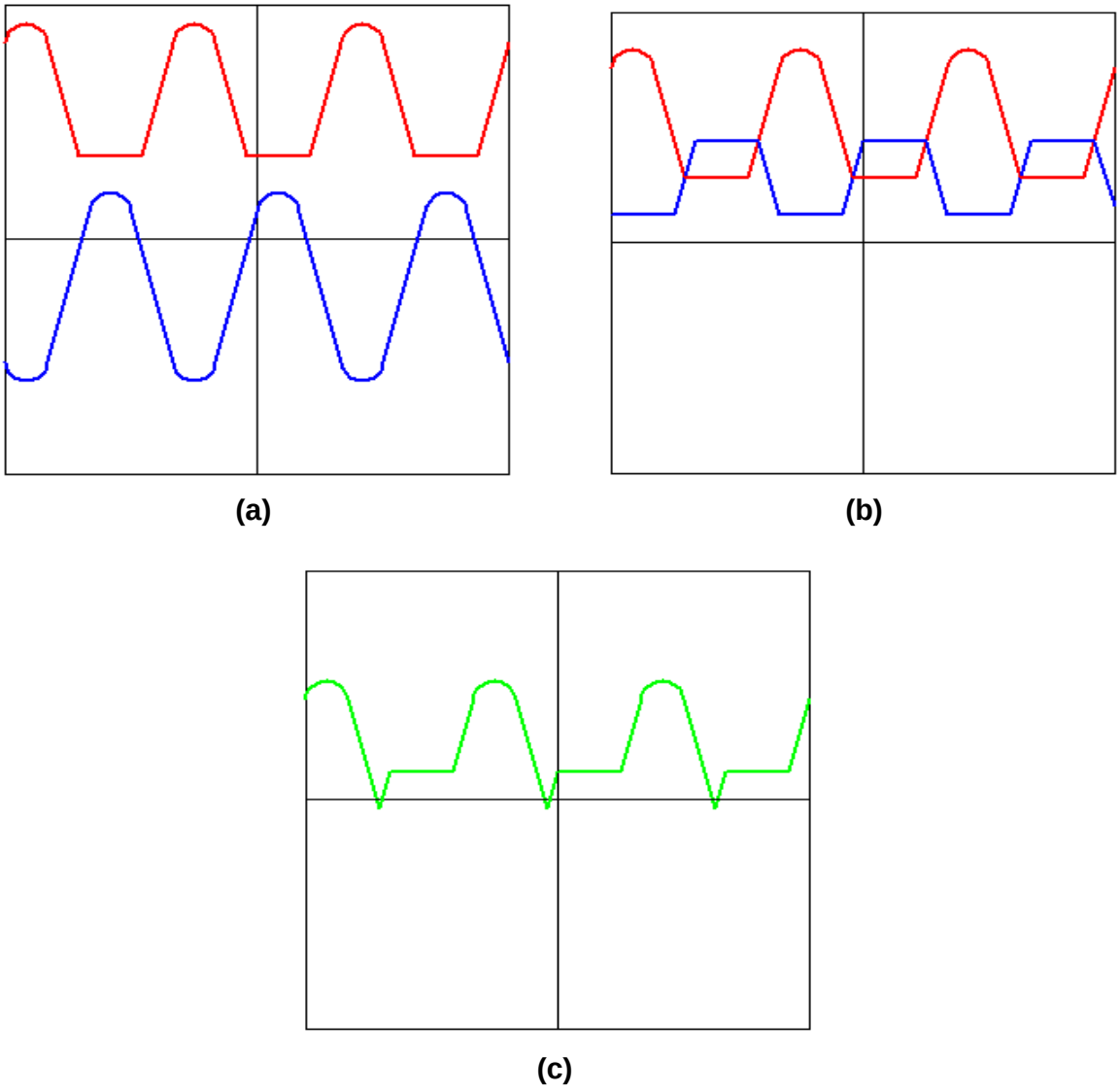
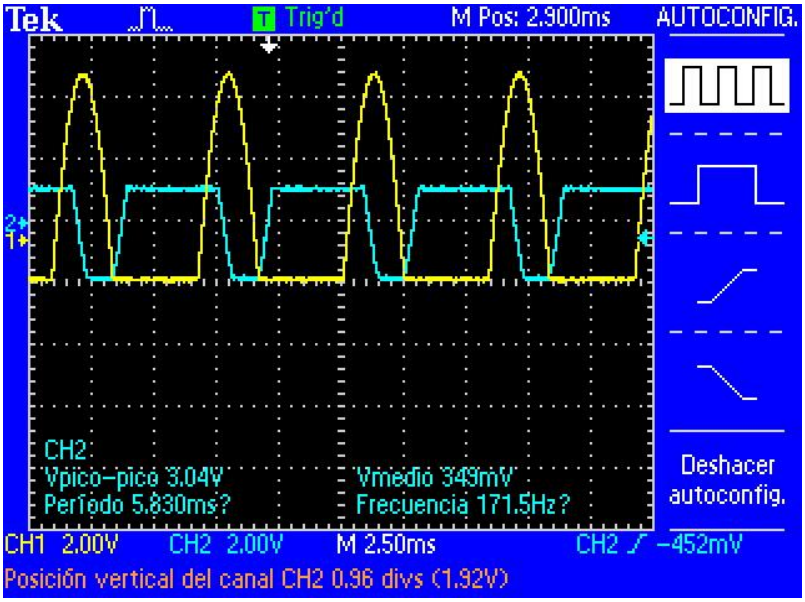


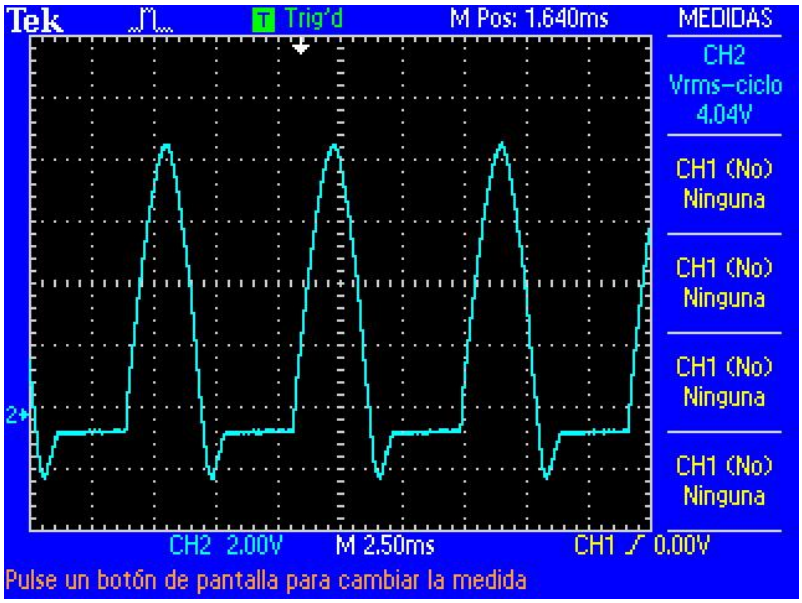
Figure 6. Reconstruction of Artificial biopotential. Results obtained by simulating the artificial neuron (Figure 4). (a) cut signal (red) and outdated signal (blue). (b) clipped signal (red) and cut outdated inverted signal (blue), (c) Sum of signals. Taken Hernandez, Jimenez and Ramirez, 2011.

RESULTS.

The artificial neuron of Figure 5 was implemented and tested in the laboratory, a Tektronik oscilloscope for viewing and scanning of artificial biopotential, Figure 7 was used.



(a)



(b)

Figure 7. Reconstruction of Artificial biopotential. Results obtained in the laboratory implement artificial neuron (Figure 4). (A) cut signal (red) and cut outdated inverted signal

(blue), (c) Sum of signals, artificial biopotential. Taken Hernandez, Jimenez and Ramirez, 2011.

DISCUSSION

In this paper it was proposed and built, was replicated, an artificial neuron with basic electronic components: resistors, capacitors and amplifiers operations.

The advantages of using these components become evident when you want to move this kind of electronics to an integrated circuit, ie when designing, integrating and synthesizing the circuit with the desired function, can achieve high levels of integration due the nature of the basic electronics used.

The appeal of our circuital synthesis, is the flexibility to change the gain values and thus adjust to the values of the potential required to emulate the behavior of biological neurons.

According to the simulation results (Figure 6) and implementation (Figure 7) shows that our artificial neuron is capable of generating an artificial biopotential with the characteristics shown in Figure 2. The next step is to take Our proposal for an integrated circuit.

Moreover, our artificial neuron, can also be used as an educational tool and would be of great help to convey to students (both biology and engineering area) in the classroom, concepts such as plasma membrane, synapses, action potential that always we mentioned but it is difficult to imagine if not put into practice.

CONCLUSIONS

The information on our SNC is transmitted from one neuron to another through electrical and chemical signals. The, known as action potentials or biopotential electrical signals are particularly important for the transport of sensitive information because they can travel quickly and cover long distances, which is why the importance of his study.

Our proposal represents a link that will lay the foundation for later, to implement complex neural circuits. An example of this would be to implement neural circuit via nociceptive (pain perception) which could be used to provide sensations robotic parts, and what is more sensitivity to incorporate prostheses for patients who have lost limbs.

The results obtained so far, make us restate our initial question: is it possible replicarnos?

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