Efficient VLSI Implementation of Digital Artificial Neuron using System Verilog

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ABSTRACT
The purpose of this paper is to study and simulate the behavior of a biological neuron, how nervous impulses, the so-called spikes, are transmitted through the body of the neuron, from the dendrites to the axon. And with this knowledge, to emulate this behavior with the target getting a system, in Verilog, that works exactly in the same way that a biologic neuron. For this, it is important to know how, why and in what circumstances a neuron is fired. From an electronic point of view dendrites of a neuron are considered as inputs, and the axon as an output. Nervous impulses are interpreted as electrical signals. The artificial neuron will be used in other applications, so that, the codification of the program that emulates the neuron will have be extrapolated to other systems to get a complete neural network. With the codification in Verilog of the artificial neuron a FPGA can be programmed for future applications of computational neuroscience as well as artificial intelligence.
Keywords— Biological neuron, Artificial intelligence, Excitatory Postsynaptic Potential (EPSP), potential generator.

I. INTRODUCTION

A neuron can be compared to a black box composed of few inputs and an output. Like an electrical circuit that makes the addition of the different signals that receives from other units and obtain in the output according to the result of the addition with relation to the threshold. The artificial neuron is an electronic device that responds to electrical signals. In our brain, there are billions of cells called neurons, which processes information in the form of electric signals. External information/stimuli is received by the dendrites of the neuron, processed in the neuron cell body, converted to an output and passed through the Axon to the next neuron. The next neuron can choose to either accept it or reject it depending on the strength of the signal. Functionally, a neuron can be divided in three parts: Soma: The body of the neuron. Dendrites: Branches that transmit the action potentials from others neurons to the soma. Axon: A branch that transmits the action potential from the neuron to other cell.

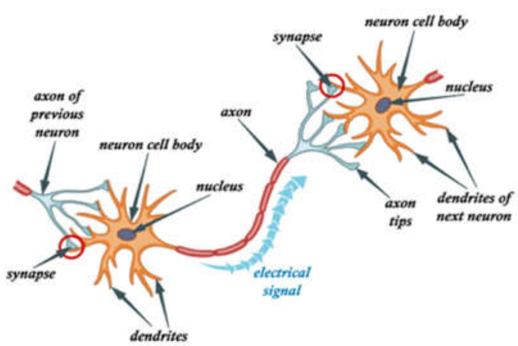

Figure 1: Parts of Neuron.

Step1. External signal received by dendrites.
Step2: External signal processed in the neural cell body.
Step3: Processed signal converted to an output signal & transmitted through the axon.
Step4: Output signal received by the dendrites of the next neuron through the synapse

The soma is the central unit of the neuron, it receives signals from others neurons across the different dendrites. If the addition of these signals is over of a certain threshold an output signal, a spike, is generated. The spike is propagated by the axon to other neurons. The contact site between the axon of the first neuron and the dendrites of the next neurons is called synapse. The spikes are short electrical pulses. The amplitude of theses spikes, are about 100 mV and they have duration of 1 or 2 ms. A spike train is a chain of action potentials emitted by a neuron, the importance of action potentials is in the timing and the numbers of spikes, the form of the action potential does not carry any information, since they all look almost the same. The spike is the elementary unit of signal transmission.

When a neuron is fired, it generates a action potential, this action potential is transmitted and processed in the soma of the next neuron, where action potential from others neurons are arriving. The soma considers all the input from the different neurons and makes a non-linear addition of these signals. The sum of this addition gives the membrane potential of the neuron, which is transmitted along the axon to target neurons. During the summation process, not all the inputs have the same relevance, thus, some are more important (represented as higher weight values) whereas other inputs are less important (lower weight values). One of the characteristics of the biological as well as artificial neuronal network is their capacity of learning, for that, the inputs has adaptive weights.

II. PROPOSED WORK & METHODOLOGY

The human nervous system has been treated by numerous studies. Not only from a medical point of view, as treatments for prevention of diseases, but also, from a technological point of view, trying to emulate the behavior of the biological neuron. And based on this, modeling an artificial neuron can be used. The following research is based exactly in this issue, to understand the real behavior of a biological neuron and according to this being able to model an artificial neuron that works in a similar way. When this artificial neuron will be developed, it will be used in future applications through complete neural networks for applications as commented previously. This model will have some inputs that will emulate the dendrites of the neuron and a pulse will be obtained as a response, which will be propagated to other neurons across the axon.

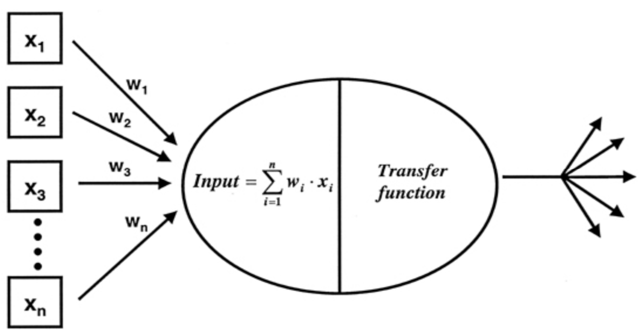

Figure 2: Analysis of a neuron.

The inputs (x1, x2, x3…xn) and their respective weights (w1, w2, w3…wn) here, w1, w2, w3….wn gives the strength of the input signals. In the processing unit or soma, firstly the addition of all inputs is realized and after that a signal is generated to be transmitted to others neurons. The system must be able to receive the spikes from others neurons, to process these inputs emulating the events that happen when a spike is arrived, making the comparison between the threshold and the addition of potentials and generated a potential action when it is needed. Besides, we have to consider others factors, like the effects of the absolute refractory time, and the importance of the different weights in the response of the system.

A. Block Diagram of Proposed System

Global system is represented in the following figure. We can observe the 3 inputs from the dendrites and their respective weights. The other input showed in the figure is the “clk” input, needed to synchronize the counter of the timer and inhibit blocks. The implementation of this neuronal model will be carried out in Verilog language. Verilog is a Hardware Description language used to model an electronic system. We have used this language because, in a future, this code will be valid to program a FPGA following applications. This language is used to program and design digital circuits, for that, all signals will be digital signals.

The way to solve this problem is to use a Top-Down method, which is to divide complex design into easier one or module. Further each module is divided into subsystems. For the developing of the system we have used a system based in an artificial neuron with only three dendrites as inputs, actually, the numbers of simultaneous spikes, in a short period of time, needed to excite a neuron are about 50 but we think that 3 dendrites are enough to show how a neuron works. To get that these 3 dendrites will be able to fire the output, we will have to increase the value of the weights, associated with the dendrites. They are defined like variables, can let the possibility of change the values to make a dendrite more significant than others.The use of weights is very important weights are associated to the synapses and can increase or decrease the signals that arrive to a synapse. As mentioned earlier, we have defined 3 variable weights as inputs, every weight is associated with a dendrite to let that the global neuronal network let the ability of learning.

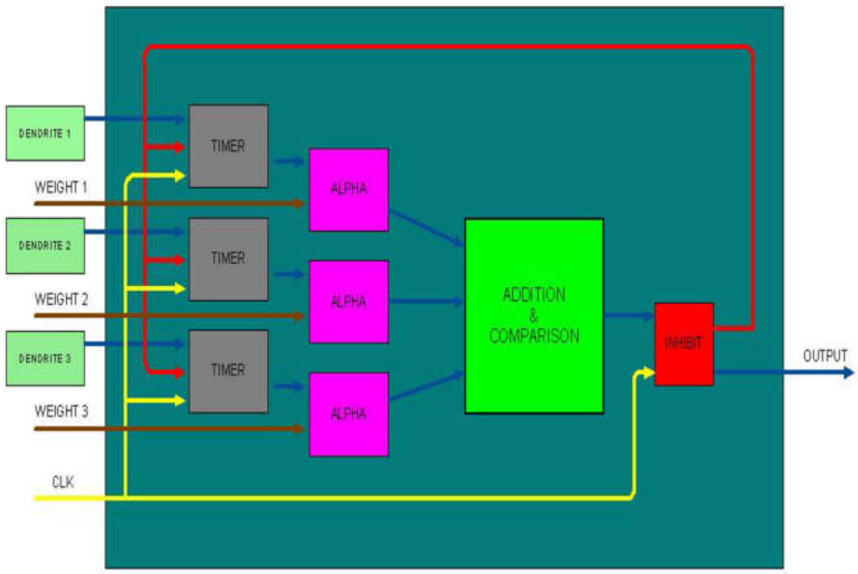

Figure 3: Block Diagram of the Neuron.

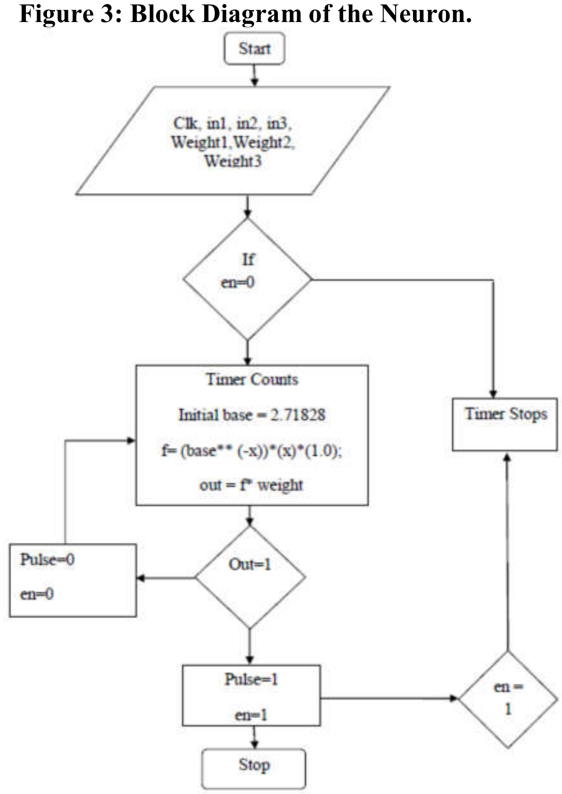

Figure 4: Flow diagram.

III. RESULTS

A. Timer Block: In this simulation we can observe the correct behavior of the program. When the signal input1 is active the count1 starts, count1 is increased gradually according to the clk signal. When enable is active count1 is reset and wait until the input1 is active again.

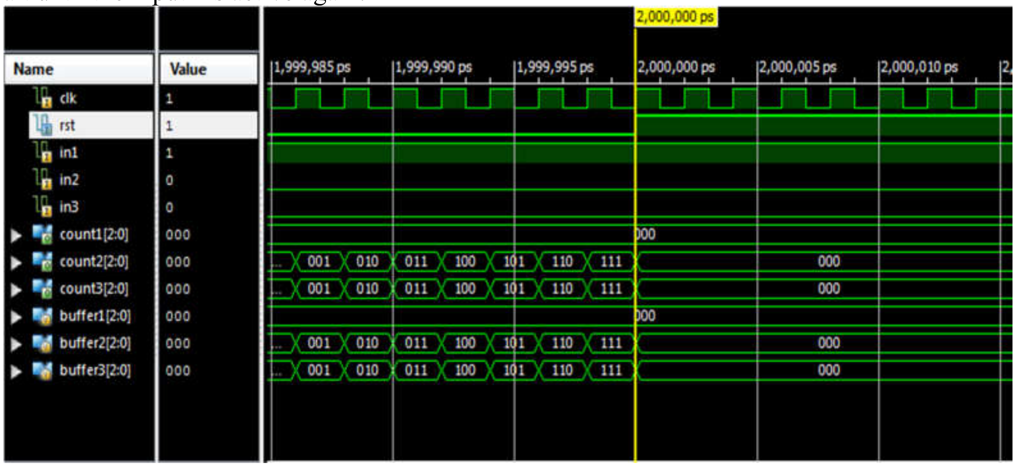

Figure 5: Simulation of Timer.

B. Alpha block

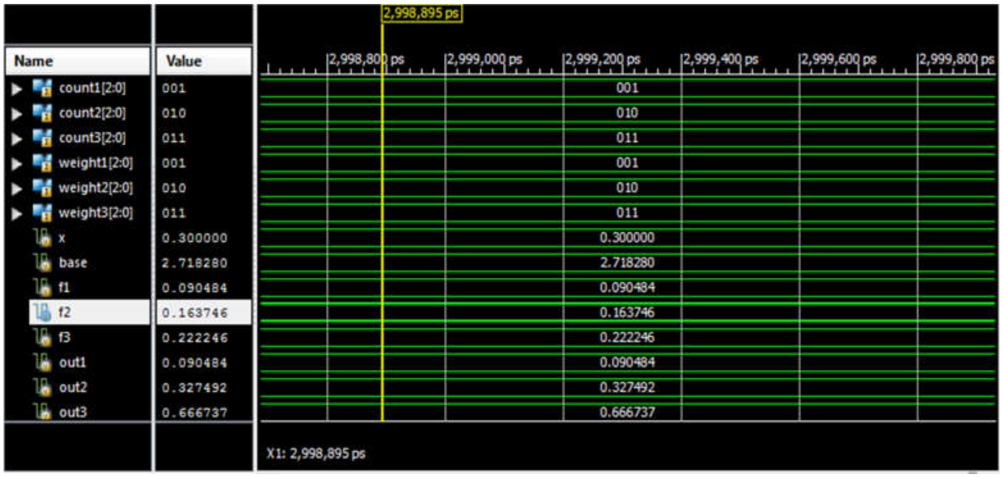

Figure 6: Simulation of Alpha.

C. Addition and Comparison

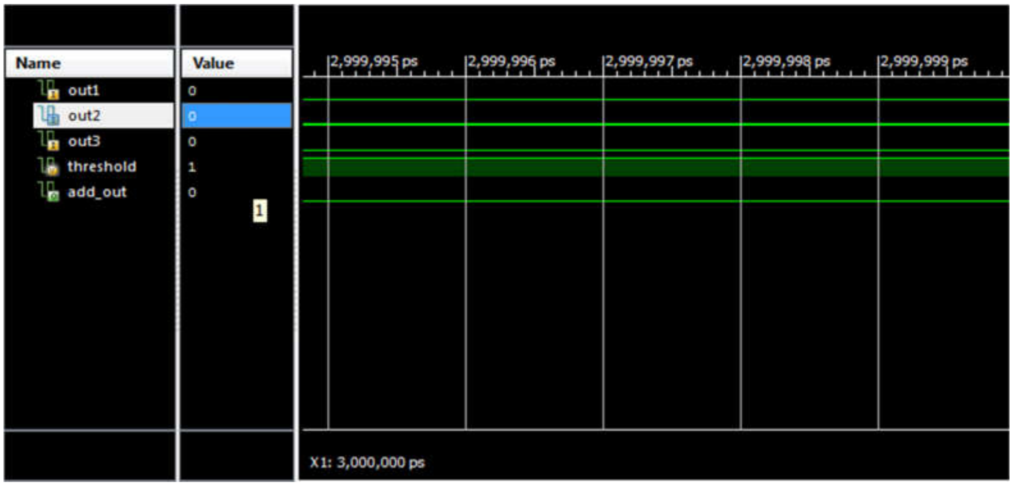

Figure 7: Simulation of Addition & Comparison.

D. INHIBIT

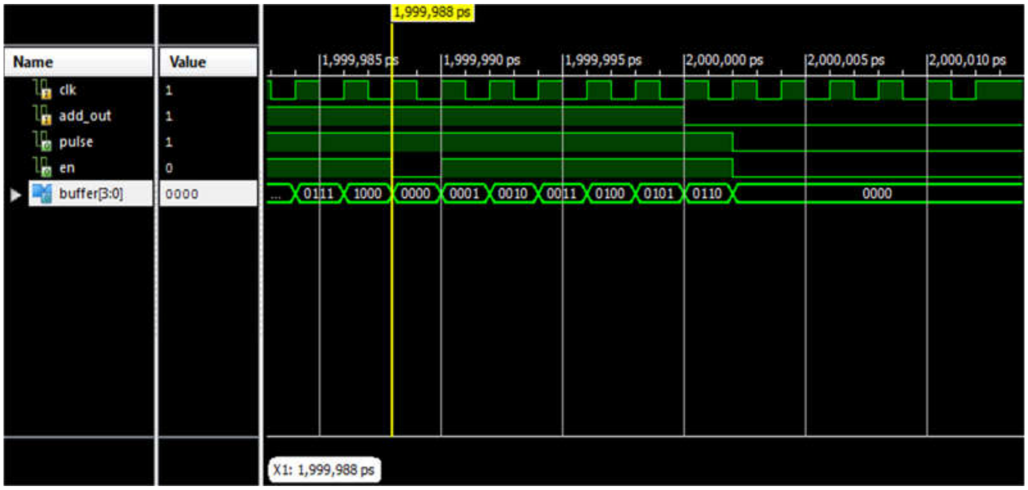

Figure 8: Simulation of Inhibit.

E. Main module

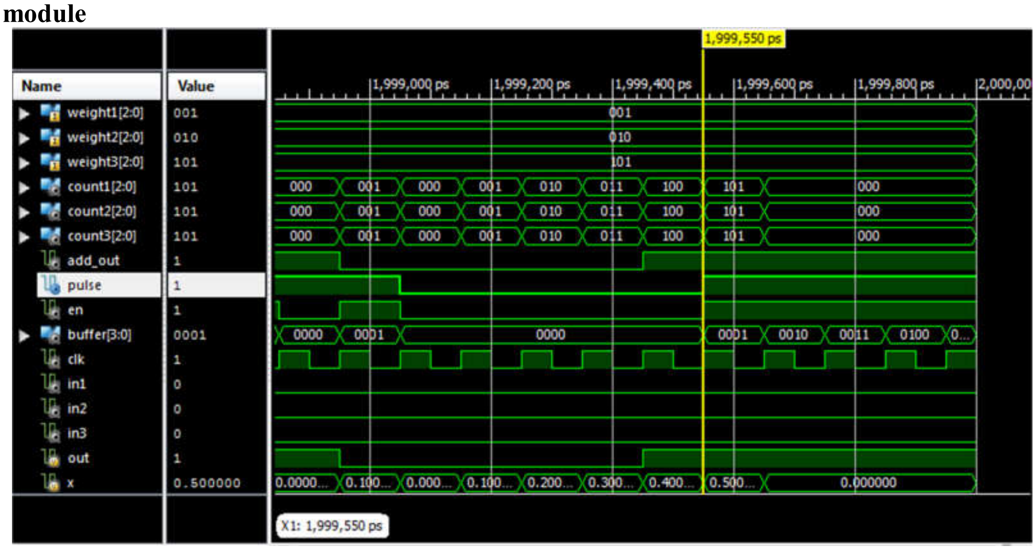

Figure 9: Simulation of main module.

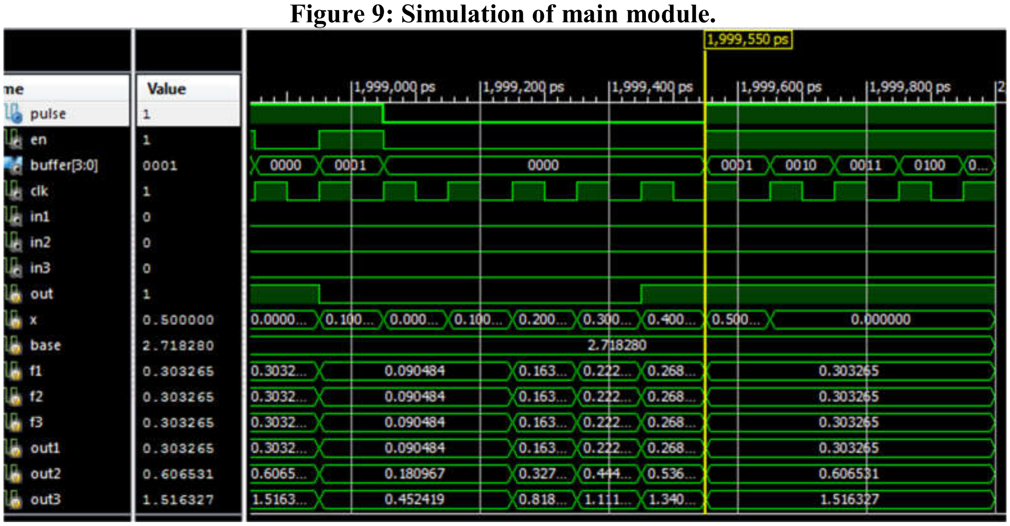

Figure 10: Simulation of main module.

IV. CONCLUSION

The basic behavior of the biological neuron can be emulated in an artificial neuron. A biological neuron with their dendrites, soma and axon can be characterized in an artificial neuron as a black box with inputs and an output. To implement the system the electronic pulses or spikes transmitted through neurons are replaced by digital signals or pulses. We can get to emulate the potential actions in the pre-synaptic and postsynaptic reactions using timers and multiplier blocks. With all these things we get an electronic system that reproduces the behavior of the biological neuron. The aim is to have the possibility of interconnect more of these artificial neurons to create a complete neuronal network. In this paper, it is only having focused our efforts to create an only artificial neuron with the help of Verilog Code.

REFERENCES

[1]. Shahin. M A, Mark. B J, Holger. R M, "Recent advances and future challenges for artificial neural systems in geotechnical engineering applications", Advances in Artificial Neural Systems, 2009; Vol. l (1), pp 1-9.
[2]. Volanis. G, Antonopoulos. A, Hatzopoulos. A A, Makris. Y, "Toward Silicon-Based Cognitive Neuromorphic ICs—A Survey", IEEE Design and Test, 2016, Vol. 33(3), pp 91-102.
[3]. Mishra. A, Raj. K, "Implementation of a digital neuron with nonlinear activation function using piecewise linear approximation technique", Proc. IEEE International Conference on Microelectronics, 2007, pp 69-72.
[4]. Sutherland. S, Mills. D, "Synthesizing system Verilog busting the myth that system verilog is only for verification", SNUG Silicon Valley, 2013.
[5]. Sibi. P, Jones, SA, Siddarth. P, "Analysis of different activation functions using back propagation neural networks", Journal of Theoretical and Applied Information Technology, 2013, Vol. 47(3), pp 1264-1268.
[6]. Gaidhane. V H, Hote. Y V, "Emotion recognition using eigen values and Levenberg-Marquardt algorithm based-classifier", 2016, Vol. 41(4), pp 415-423.
[7]. Kantabutra. V, "On hardware for computing exponential and trigono-metric functions", IEEE Trans. On Computers, 1996, Vol. 45(3), pp 328-339.
[8]. Leboeuf. K, Muscedere. R, Ahmadi. M, "Performance analysis of table-based approximations of the hyperbolic tangent acti-vation function", Proc. IEEE 54th International Midwest Symposium on Circuits and Systems, 2011, pp 1-4.
[9]. Haghiri. S, Ahmadi. A, Saif. M, "Complete neuron-astrocyte interaction model: digital multiplierless design and networking mechanism", IEEE Trans. on Biomedical Circuits and Systems, 2017, Vol. 11(1), pp 117-127.
[10]. Smith D, Franzon, Verilog Style for Synthesis of Digital System, Prentice Hall, New York.
[11]. Wolf W, Modern VLSI Design: System on Chip Design, 3rd Edition, Prentice Hall, New York, 2011.
[12]. Haykin S, Neural Networks, A Comprehensive Foundation, 2nd Edition, Prentice Hall, New York, 1999.