A REALIZATION of SC-CNN-BASED CIRCUIT USING FTFN

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ABSTRACT

In this paper, a realization of the State Controlled Cellular Neural Network (SC-CNN)-based circuit using FTFN is presented. In this realization, a new version of autonomous Chua's circuit has been considered using FTFN realization of SC-CNN-based circuit. The performance of the proposed SC-CNN-based circuit is demonstrated by PSpice simulations.

I. INTRODUCTION

In recent times, many studies were reported about chaotic circuits and their applications. From this point of view, a variety of chaotic circuits have been used as chaos generator. Since it exhibits a rich variety of bifurcations and chaos, the most preferable circuit as the chaos generator is Chua's circuit [1].

On the other hand, since its definition by Chua&Yang [2], Cellular Neural Networks (CNNs) received a great deal of interest. Although many of these applications were proposed for numerous disciplines like artificial life and image processing [3], some have been adapted for chaos [4-7]. In one of these applications, Arena et al. realized unfolded Chua's circuit using the connection of three simple generalized CNN cells and called this network structure as State-Controlled CNN (SC-CNN) [4]. The proposed SC-CNN-based circuit is realized by using voltage-mode op amp (VOA) as an active element. Afterwards this SC-CNN based circuit has been used in the chaos-based secure communication systems as a chaos generator [5,6].

As an active element, VOAs have been used in a broad band of applications, e.g. filters, linear and non-linear amplifiers, analogue simulations etc. In the evolution of VLSI circuits, because of VOA's certain limitations such as slew-rate problem and fixed gain-bandwidth product, designers changed the processed signal from voltage to current [8].

On the other hand, current-mode circuits are receiving much attention for their potential advantages such as wider dynamic range, inherent wide bandwidth, simpler circuitry and lower power consumption than voltage-mode circuits [9,10]. Among the current-mode circuits, four terminal floating nullor (FTFN)-based current-mode circuits are more flexible, versatile and stable active element in the synthesis of active networks than VOAs and current conveyors [8-13]. Because of the potential advantages of current-mode signal processing techniques, in literature many methods have been investigated for transforming the well-developed voltage-mode circuit into their current-mode counterparts through the use of nullor model [9]. One of the implementations of the nullor model is an ideal voltage-mode op amp (VOA). It has been shown that, the nullor equivalent of VOA can be replaced with the nullor equivalent of FTFN without imposing any restrictions [13].

In this paper, by utilizing the transformation between VOA and FTFN, the circuit realization of SC-CNN-based circuit has been constituted with FTFN. The organization of the paper is as follows: In Section 2, the generation of Chua's circuit dynamics using SC-CNNs is given. In Section 3, the circuit realization of the SC-CNN-based circuit using FTFN is described and simulation results are presented and finally a conclusion part is presented in Section 4.

II. SC-CNN-BASED CIRCUIT

As the most preferable chaos generator, diverse realizations of Chua's circuit have been used in several applications. One of the realizations of Chua's circuit has been derived by using a suitable connection of three simple generalized CNN cells. The proposed circuit has been called as the State Controlled-Cellular Neural Network (SC-CNN) [4]. While the dimensionless state equations of the Chua's circuit are defined as follows:

$$\dot{x} = \alpha[y - h(x)]$$
$$\dot{y} = x - y + z \qquad (1)$$
$$\dot{z} = -\beta y - \gamma z$$

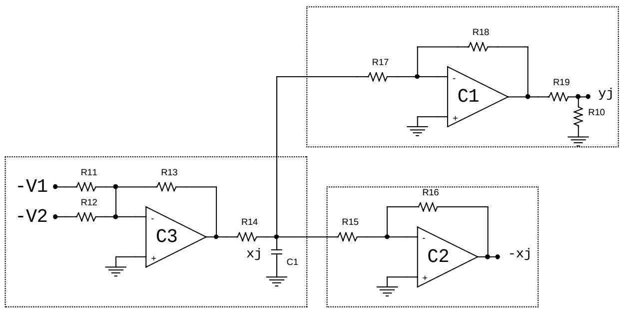
where

$$h(x) = m_1 x + 0.5 \cdot (m_0 - m_1) \times (|x+1| - |x-1|) \qquad (2)$$

the proposed SC-CNN-based circuit is defined by the following nonlinear state equations [4]:

$$\begin{aligned} \dot{x}_1 &= -x_1 + a_1 y_1 + s_{11} x_1 + s_{12} x_2 \\ \dot{x}_2 &= -x_2 + s_{21} x_1 + s_{23} x_3 \\ \dot{x}_3 &= -x_3 + s_{32} x_2 + s_{33} x_3 \end{aligned} \qquad (3)$$

To obtain SC-CNN version of Chua's circuit, the "a" and "s" parameters determined as $a_1 = \alpha(m_1 - m_0)$; $s_{33} = 1 - \gamma$; $s_{21} = s_{23} = 1$ $s_{11} = 1 - \alpha \cdot m_1$; $s_{12} = \alpha$; and $s_{32} = -\beta$ [4]. It is demonstrated that the state equations of Chua's circuit defined in Eq. (1) could be obtained with SC-CNN state equations. The generalized cell circuit can be seen in Fig 1(a).



(a)

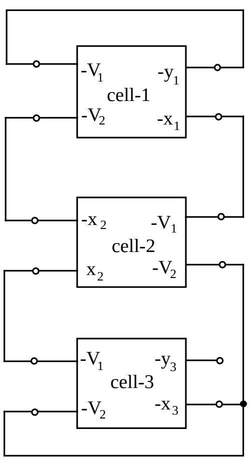


Figure 1. (a) The full circuit scheme of the SC-CNN-based circuit proposed in [4]. (b) Cell connection scheme.

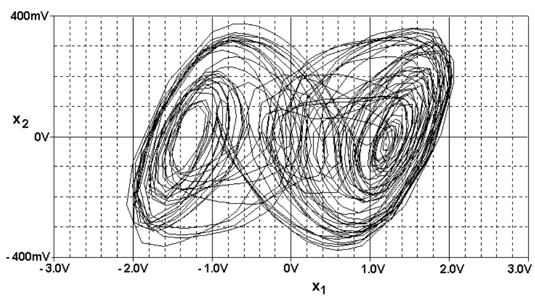
To obtain the output non-linearity, R_{17} and R_{18} designed such that the C_1 output saturates when $|x_1|>1$, and also designed R_{19} and R_{10} to scale the output voltage $-y_1$ in the range [-1,1] [4].

$$R_{18} / R_{17} = V_{satC_1} / V_{satx_1} \qquad (4a)$$
$$R_{17} / R_{18} = R_{10} / (R_{19} + R_{10}) \qquad (4b)$$

C_2 is an inverting amplifier and it has a unity gain, so $R_{15}=R_{16}$. From C_3, the SC-CNN cell state equation can be written as follows:

$$C_j x_j' = -\frac{x_j}{R_4} + \frac{R_3}{R_1 R_4} V_1 + \frac{R_3}{R_2 R_4} V_2 \qquad (5)$$

To realize Chua's circuit, the three cells connection determined as, $v_1=y_1$ and $v_2=x_2$ for the first cell, $v_1=x_1$ and $v_2=x_3$ for the second cell, $v_1= -x_2$, $v_2=x_3$ for the third cell and this cell connection scheme is given in Fig. 1(b) [4]. To perform a double-scroll chaotic attractor as in original Chua's circuit with the parameter values $\beta = 14.286$, $\alpha = 9$, $\gamma = 0$, $m_0 = -1/7$ and $m_1 = 2/7$, the parameter values of SC-CNN based circuit chosen as R_{11}=13.2 kΩ, R_{12}=5.7 kΩ, R_{13}=20 kΩ, R_{14}=390 Ω, R_{15}=100 kΩ, R_{16}=100 kΩ, R_{17}=74.8 kΩ, R_{18}=970 kΩ, R_{19}=27 kΩ, R_{10}=2.22 kΩ, C_{11}=51 nF for the first cell, R_{21}= R_{22}= R_{23}= R_{25}= R_{26}=100 kΩ, R_{24}=1 kΩ, C_{21}=51nF for the second cell, R_{32}= R_{33}= R_{35}= R_{36}=100 kΩ, R_{34}=1 kΩ, R_{31}=7.8 kΩ, C_{31}=51 nF for the third cell [4]. A double scroll between x_1-x_2 cells and dc characteristic of the SC-CNN-based circuit is shown in Fig. 2(a) and in Fig. 2(b), respectively.



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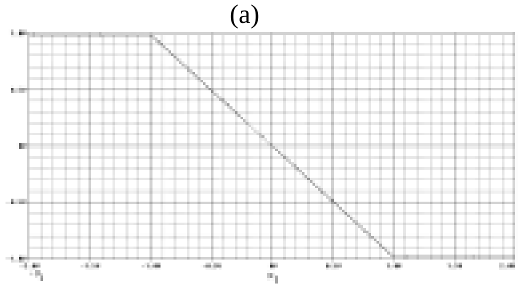


Figure 2. (a) The double scroll attractor, projection in the x_1-x_2 plane. (b) The dc characteristic of SC-CNN-based circuit.

III. FTFN REALIZATION OF SC-CNN BASED CIRCUIT

As theoretical active elements nullator with zero voltage and current, which is a one port two terminal element, and norator with arbitrary voltage and current, which is a one port two terminal, have been used in the synthesis of active networks.

The union of nullator and norrator is called "nullor" and its symbol is given in Fig. 3.

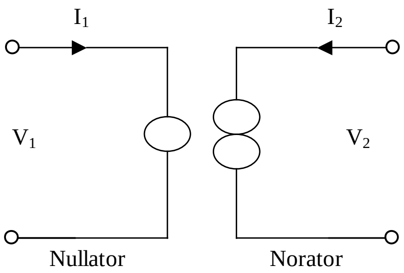


Figure 3. Symbol for nullor.

In Fig. 3, it can be seen that nullor has a nullator input and a norator output. One of the implementations of the nullor model is an ideal voltage-mode op amp (VOA).

One can consider that VOA can be realized by using norator's arbitrary output voltage and arbitrary output current characteristics, and also nullator's zero input voltage and zero input current flowing characteristics. So the nullor equivalent of the voltage-mode op amp can be seen in Fig. 4.

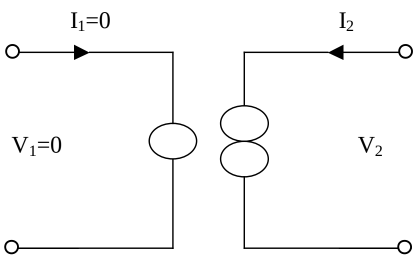


Figure 4. The nullor model of ideal voltage-mode op amp (VOA).

On the other hand, in literature the FTFN is defined as the ideal nullor [12], and its generalized nullor equivalent scheme and circuit symbol are given in Fig. 5(a) and Fig. 5(b), respectively.

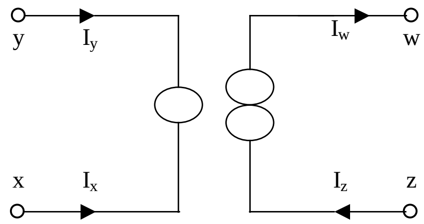


Figure 5. (a) The nullor equivalent of FTFN

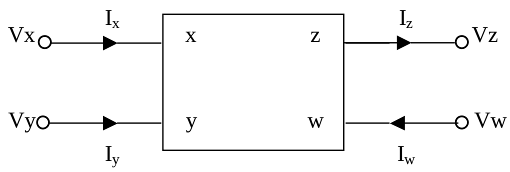


Figure 5. (b) The circuit symbol of FTFN.

The port relations of FTFN is characterized by the following equations:

$$\begin{aligned} Vx &= Vy \\ Ix &= Iy = 0 \\ Iz &= Iw \end{aligned} \qquad (6)$$

Without imposing any restrictions the nullor equivalent of FTFN used instead of the nullor equivalent of VOA. In this transformation, by determining x port as the inverting input terminal, y port as the non-inverting input terminal, w port as the output terminal of a VOA, and also z port is grounded, FTFN can behave as VOA.

In this paper, by utilizing this transformation between VAO and FTFN building blocks, without any change in the other circuit elements and circuit connections, we used FTFN blocks instead of VOAs in Fig. 1(a). We obeyed the design considerations in Eqn. 4(a) and Eqn. 4(b).

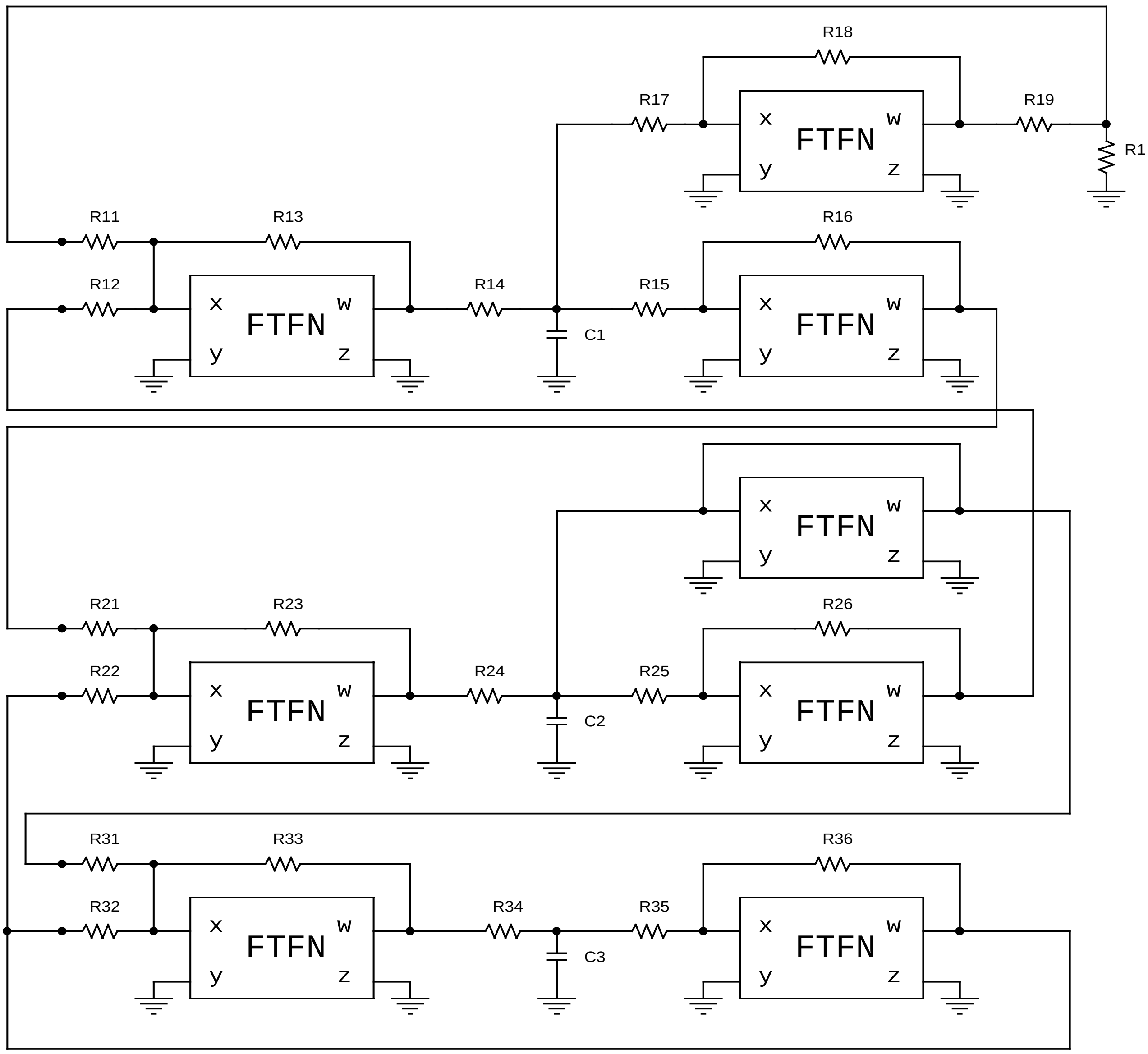


Figure 6. The proposed FTFN realization of SC-CNN-based circuit.

While there are no changes in circuit elements and circuit connections for C_2 and for C_3, to form the saturation of C_1 output when $|x_1|>1$, and to scale the output voltage $-y_1$ in the range [-1,1], the parameter values of R_{17} and R_{19} are redesigned, as 149.6K and 12.32K, respectively.

The proposed FTFN realization of SC-CNN-based circuit is given in Fig. 6 and dc characteristic of the proposed output is given in Fig. 7.

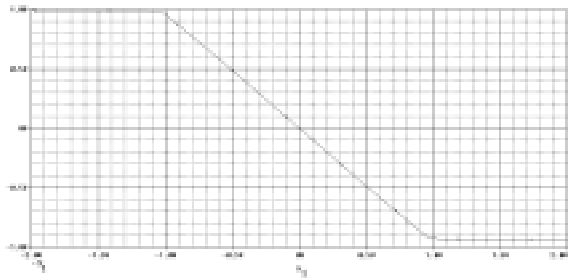
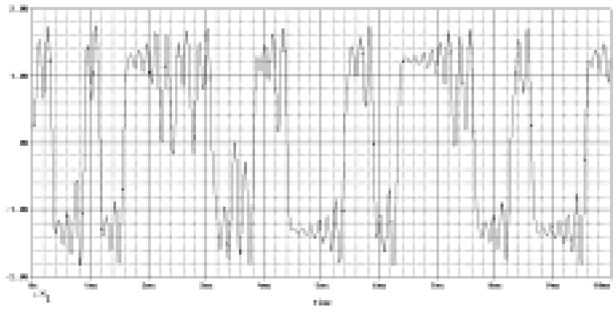


Figure 7. The dc characteristics of the proposed circuit.

To perform PSpice simulations, a CMOS realization of FTFN, is used in literature with the same parameters [11]. While the chaotic waveforms and double scroll attractors of the proposed circuit are illustrated in Fig. 8 and in Fig. 9, respectively.



(a)

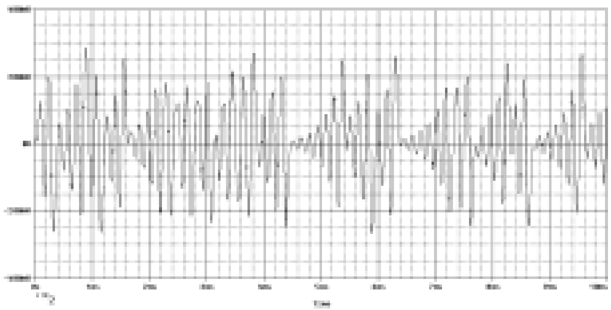


Figure 8. (a) x_1 dynamic of the proposed SC-CNN based circuit. (b) x_2 dynamic of the proposed SC-CNN based circuit.

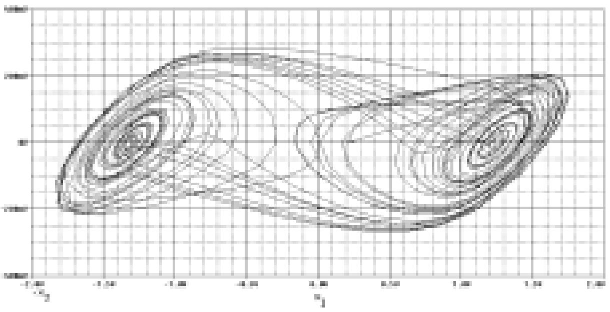


Figure 9. Double-scroll between x_1-x_2.

IV. CONCLUSION

A FTFN realization of SC-CNN-based circuit has been introduced. By using FTFN instead of VOA, an alternative circuit realization of SC-CNN-based circuit has done. From simulation results, it can be seen that the proposed FTFN realization of SC-CNN-based circuit can be used as a chaos generator in chaos based secure communication systems.

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