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Synthesis of CCII-s by superimposing VFs and CFs through genetic operations

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Abstract: It is introduced a new genetic algorithm to synthesize the negative-type second generation current conveyor (CCII-) by superimposing a voltage follower (VF) with a current follower (CF). First, the VF and CF are described by binary genes. Second, the gene CF is inverted, rigth-shifted and multiplied (AND operation) with the gene VF to verify that both genes can be superimposed to synthesize the CCII-. Finally, some synthesized CCII-s are presented which electrical characteristics are measured using HSPICE and standard CMOS technology of 0.35 μm.

Keywords: evolutionary electronics, circuit synthesis, current conveyor, nullor

Classification: Integrated circuits

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1 Introduction

Evolutionary electronics is a research area which involves the application of evolutionary algorithms [1, 2, 3, 4, 5, 6, 7]. Basically, evolutionary computation is inspired by Darwinian evolutionary theory which is oriented to recreate biological phenomena by using computers and other artificial systems.

Analog design is much amenable for evolutionary techniques, where contrasting with digital design, there is no solid set of design rules or procedures

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to automate circuit synthesis. For instance, genetic algorithms (GAs), which operates on the principle of survival of the fittest, have the capability to generate new design solutions from a population of existing solutions, and discarding the solutions which have an inferior performance or fitness. GAs begin with an initial collection of random solutions called initial population. Each individual in the population is called chromosome and represents a possible solution to the problem. A chromosome is a chain of symbols called genes, which generally are represented by binary strings. The chromosome evolves through iterations called generations. In each generation the chromosomes are evaluated using an aptitude measure. The next population is formed by descendents created by combining two chromosomes of the current generation using the crossover and the mutation operators. On the other hand, since current conveyors have received a lot of attention [8, 9, 10, 11, 12, 13, 14], in this paper is introduced a new GA to synthesize the negative-type second generation current conveyor (CCII-).

The proposed synthesis approach uses nullors [15], to codify the abstract behavior of the voltage follower (VF) [16, 17], and current follower (CF) [18]. Further, the VF and CF are superimposed [19], to synthesize the CCII-. In this manner, the genetic representation of the VF and CF is described in Sect. 2. The superimposing of the VF and CF is shown in Sect. 3, but by applying binary genetic operations, instead of performing matrix operations [5, 19]. Finally, some synthesized CCII-s are presented in Sect. 4, along with their sizes and electrical characteristics measured using HSPICE and standard CMOS technology of 0.35 μm.

2 Genetic representation of VFs and CFs

The synthesis of CMOS compatible VFs and CFs has been already presented in [1, 16, 17, 18]. Furthermore, in this section is described the genetic representation of them, in order to perform a sumperimposing operation to synthesize the CCII-, as shown in Sect. 3.

The use of ideal or simplified models enhances the automatic synthesis of analog circuits [5, 6, 7]. That way, using nullators and norators [15], it is possible to describe the behavior of VFs and CFs [1], where for synthesis purposes, a nullator (O) and a norator (P) always must form a joined-pair. The node in the joined terminals of the O-P pair is associated to the source (S) of a MOSFET, the other terminal of the O element is associated to the gate (G), and the other terminal of the P element to the drain (D) [16].

2.1 Genetic representation of the VF

In Fig. 1 (a) is shown the nullor-based description of a VF consisting of four O elements (O1-O4), each one joined with a P element. As already shown in [1] and [17]: the O-P pairs can be described by a small-signal gene called genSS, the synthesis of each O-P pair can be codified by the gene called genSMos, the addition of biases (V and I) can be codified by the gene called genBias, and the synthesis of current biases by current mirrors (CMs) can be codified

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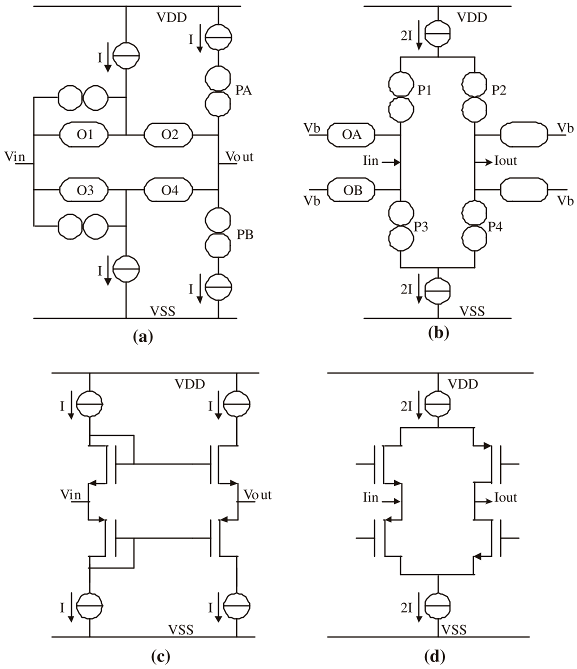

Fig. 1. (a) VF and (b) CF description using nullors, and synthesized (c) VF and (d) CF using MOSFETs.

by the gene called genCM. As a result, the genetic representation of the VF consists of a chromosome of four ordered genes, as shown by Eq. (1). By using n as the number of O-P pairs, and m as the number of bits for genCM, the length of Eq. (1) is calculated by Eq. (2).

$$\text{Chromosome}_{VF} = genSS{*}genSMos{*}genBias{*}genCM \tag{1}$$

$$\text{LengthChromosome}_{VF} = 2n + n + 2n + m \tag{2}$$

2.2 Genetic Representation of the CF

In Fig. 1 (b) is shown the nullor-based description of a CF consisting of four P elements (P1-P4), each one joined with an O element. As already shown in [1]: the O-P pairs can be described by a small-signal gene called genSS, the synthesis of each O-P pair can be codified by the gene called genSMos, the addition of current biases is done as for the VF and codified by genBias. However, since the input and output signals in the CF are currents, and since they are injected or measured at the D or S terminals of the MOSFETs, then each G of each MOSFET must be biased with a voltage-bias source which can be positive or negative. This process is codified by one bit for each O element (Vb in Fig. 1 (b)), to represent the gene genVbias. Finally, the synthesis of current biases by CMs is codified by the gene genCM. As a result, the genetic representation of the CF consists of a chromosome of five ordered genes, as shown by Eq. (3). By using n as the number of O-P pairs, and m as the number of bits for genCM, the length of Eq. (3) is calculated by Eq. (4).

$$\text{Chromosome}_{CF} = genSS{*}genSMos{*}genBias{*}genVbias{*}genCM \tag{3}$$

$$\text{Length Chromosome}_{CF} = 2n + n + 2n + n + m \tag{4}$$

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3 Superimposing VFs and CFs

By applying the superimposing method presented in [19], between Fig. 1 (a) and Fig. 1 (b), it is clear that O2-PA and O4-PB can be superimposed with OA-P1 and OB-P3, respectively. If the O-P pairs are sinthesized by MOSFETs, the resulting VF and CF are shown in Fig. 1 (c) and Fig. 1 (d), where the MOSFETs connected at node Vout can be superimposed to the MOSFETs at node Iin, as ready shown in [18], to generate the CCII-.

To avoid the evaluation and matrix operations proposed in [19], the superimposing can be done by performing binary operations using only *genSS*. In this manner, *genSS* in Eq. (1) is codified by Eq. (5) [17], and in Eq. (3) it is codified by Eq. (6) [1]. Furthermore, by adopting the O-based description and P-based description from Fig. 1 (a) and Fig. 1 (b) for the VF and CF, the superimposing is done as follows: Invert the gene CF, shift-right two bits gene CF, and make an AND operation between gene VF and the modified gene CF, if the resulting operation leads to Eq. (7) both circuits can be superimposed, otherwise search for a new either or both VF and CF.

$$genSS_{VF} = \underbrace{11}_{O1}\underbrace{01}_{O2}\underbrace{11}_{O3}\underbrace{01}_{O4} \quad (5)$$

$$genSS_{CF} = \underbrace{10}_{P1}\underbrace{01}_{P2}\underbrace{10}_{P3}\underbrace{01}_{P4} \quad (6)$$

$$genSS_{VF} * genSS_{CF} = XX01XX01 \quad (7)$$

By superimposing Eq. (5) and Eq. (6): the invertion of gene CF leads to 01100110, shifting-rigth two bits leads to XX011001, and making the AND operation it leads to XX011001. Since bits 3, 4, 7 and 8 are the same as the ones in Eq. (7), both circuits can be superimposed to generate a CCII-.

4 Synthesized CCII-s

By applying the GA already introduced in [1, 17], and by applying the superimposing procedure described in Sect. 3, six practical CCII-s are shown in Fig. 2. It can be seen that the superimposing of the VF and CF shown in Fig. 1 (c) and Fig. 1 (d), leads to the CCII-s shown in Fig. 2 (c) and Fig. 2 (e), where Vb is connected to the Z terminal and ground, respectively.

Finally, the sizes of each CCII- by applying the procedure given in [20], are shown in Table I, and also their electrical characteristics which were measured using standard CMOS technology of 0.35 μm, with L = 1 μm, Iref = 50 μA and VDD = −VSS = 1.5 V.

The proposed procedure can be extended to synthesize inverting CCII-s by superimposing VMs [17], instead of VFs, with CFs. Another current conveyors can be synthesized by exploring on the superimposing of VFs, VMs, CFs and CMs.

5 Conclusion

It has been introduced a new GA for the superimposing of VFs with CFs to synthesize CCII-s. The main advantage of the proposed superimposing

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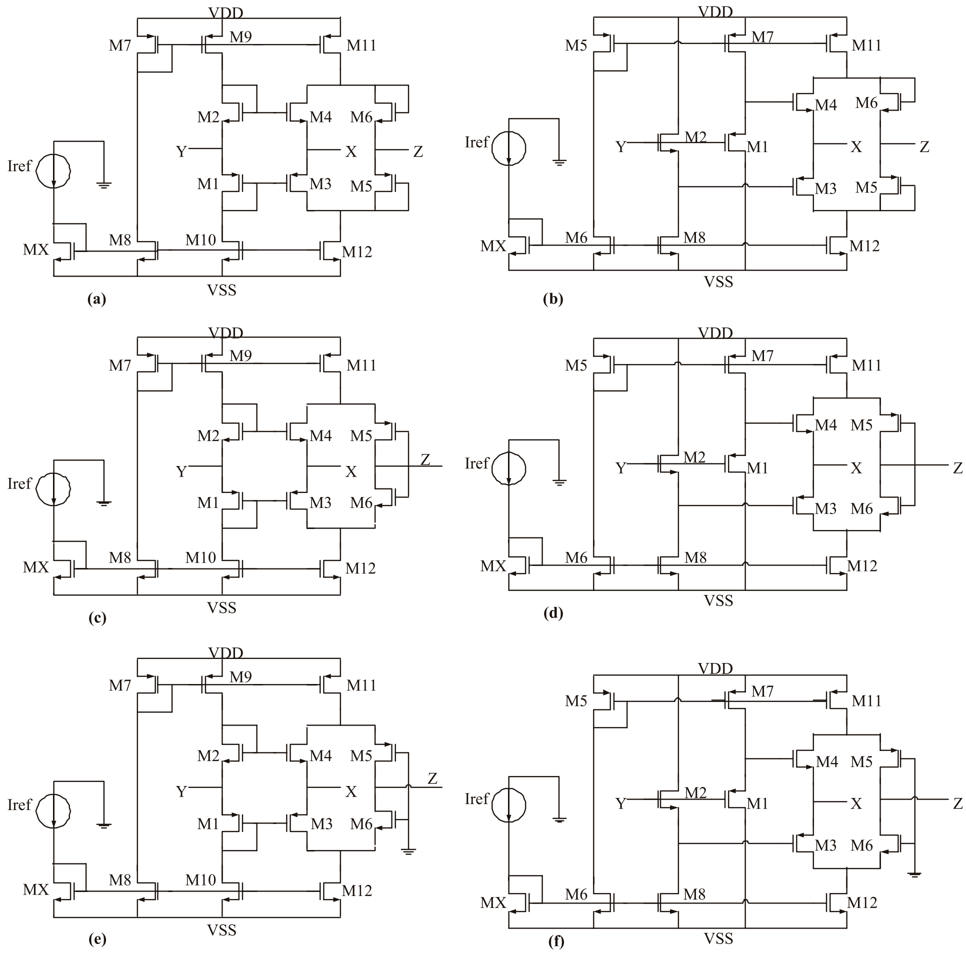

Fig. 2. Synthesis of CCII-s by superimposing a VF with a CF.

Table I. Sizes and characteristics of the CCII-s in Fig. 2.

	Fig. 2 (a)	Fig. 2 (b)	Fig. 2 (c)	Fig. 2 (d)	Fig. 2 (e)	Fig. 2 (f)
W_{M1}	192.35 μm	21.35 μm	192.35 μm	21.35 μm	192.35 μm	21.35 μm
W_{M2}	25 μm	6 μm	25 μm	6 μm	25 μm	6 μm
W_{M3}	192.35 μm	48 μm	192.35 μm	48 μm	192.35 μm	48 μm
W_{M4}	25 μm	2.35 μm	25 μm	2.35 μm	25 μm	2.35 μm
W_{M5}	192.35 μm	192.35 μm	192.35 μm	192.35 μm	192.35 μm	192.35 μm
W_{M6}	25 μm	25 μm	25 μm	25 μm	25 μm	25 μm
$W_{M7=M9}$	21.36 μm	21.35 μm	21.36 μm	21.35 μm	21.36 μm	21.35 μm
$W_{M8=M10=MX}$	11 μm	11 μm	11 μm	11 μm	11 μm	11 μm
W_{M11}	42.7 μm	42.7 μm	42.7 μm	42.7 μm	42.7 μm	42.7 μm
W_{M12}	22 μm	22 μm	22 μm	22 μm	22 μm	22 μm
Offset μV	78	−1100	383	−496	383	−496
Y-X Gain	0.996	0.981	0.989	0.981	0.989	0.981
Y-X TF mV	±400	±500	±400	±400	±400	±400
Y-X BW MHz	103	71.3	102	71.6	102	71.6
Offset nA	785.77	692.22	556.17	564.09	556.17	564.09
X-Z Gain	0.985	0.987	0.993	0.994	0.993	0.994
X-Z TF μA	±100	±80	±100	±100	±100	±100
X-Z BW MHz	132	178	129	194	121	179
Ry KΩ	91.36	∞	91.36	∞	91.36	∞
Rx	656.82	2020	660.91	2030	660.91	2030
Rz KΩ	45.11	39.73	102.59	99.35	30370	27650

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method, is that it performs binary operations between the genes describing the VF and CF, instead of evaluating matrix operations.

The proposed method can be extended to synthesize other kinds of current conveyors and also their inverting topologies by exploring on the superimposing among VFs, VMs, CFs and CMs.

Finally, six practical CCII-s were presented along with their sizing ratios and electrical characteristics.

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