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New CCII and ICCII Based Realizations of L-C and L-R Mutators

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Abstract New realizations of Chua L-C and L-R mutators using current conveyors (CCII) and inverting current conveyors (CCII) are introduced. Two realizations are available in the literature using CCII for each of the types of L-C and L-R mutators. For the type 1a L-R mutator three new realizations using CCII and ICCII are introduced to complete a family of four realizations. For the type 1b L-R mutator three new realizations using CCII and ICCII are introduced to complete a family of four realizations. For the type 2a L-C mutator fifteen new realizations using CCII and ICCII are introduced to complete a family of sixteen realizations. For the type 2b L-C mutator fifteen new realizations using CCII and ICCII are introduced to complete a family of sixteen realizations. For the type 2c L-C mutator eight new realizations using CCII and ICCII are introduced to complete a family of sixteen realizations. Finally for the types 2a and 2b L-R mutator fifteen new realizations using CCII and ICCII are given for each type to complete a family of sixteen realizations. Although this is a review paper and is partially tutorial it includes many new realizations of L-C and L-R mutators.

Keywords L-C mutators · L-R mutators · Current conveyors · Inverting current conveyors

1 Introduction

Chua [3] introduced two types of LC mutators, known as type 1 LC mutator (a gyrator) and type 2 LC mutator (referred to in this paper as type 2a LC mutator). Chua [3] also introduced two types of LR mutators, known as type 1 LR mutator (referred

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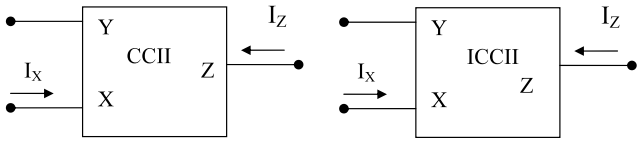

Fig. 1 (**a**) The symbol of CCII. (**b**) The symbol of ICCII

to here as type 1a LR mutator) and type 2 LR mutator (referred to here as type 2a LR mutator). These two-port linear reversible active circuit elements can be used for simulating inductors.

The realizations of the Chua family using the second generation current conveyor (CCII) [10] were introduced in [11].

The CCII family consists of two members, the two members are the CCII+ and the CCII− introduced in [10]. The inverting second generation current conveyor (ICCII) family consists also of two members, namely the ICCII+ and the ICCII− introduced in [2].

The CCII and ICCII are universal building blocks and are shown symbolically in Figs. 1(a) and 1(b) respectively and are defined by:

$$\begin{pmatrix} I_Y \\ V_X \\ I_Z \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ a & 0 & 0 \\ 0 & K & 0 \end{pmatrix} \begin{pmatrix} V_Y \\ I_X \\ V_Z \end{pmatrix}. \tag{1}$$

The parameter a represents the conveyor type, for CCII; $a = 1$ and for ICCII; $a = -1$.

The parameter K represents the Z polarity of the conveyor, for the $Z+$ polarity; $K = 1$ and for the $Z-$ polarity; $K = -1$.

The present paper introduces new realizations of LC and LR mutators using CCII and ICCII.

All the circuit realizations given in this paper referred to as realizations-A have the advantage that they can absorb most of the current conveyors parasitic element effects. When the CCII realizations of Chua family of mutators were introduced in [11] and [12, 13] two realizations were given for each mutator. At this time it was not known about the CMOS realizations of the CCII or about parasitic elements of the CCII. Now after the CMOS realization of the CCII is a reality [14] it is observed that one of the two realizations given in [11] and [12, 13] for each of the L-R mutators employ a capacitor connected to port X of the CCII which limits the frequency of operation of the circuit. These CCII realizations are referred to as realizations-B and are not included in this paper.

2 Converter Type L-R Mutators

It is well known that there are two types of L-R mutators [11, 13] that belong to the voltage generalized impedance converter (VGIC). In this section the basic definitions are reviewed and new realizations are introduced using CCII and ICCII.

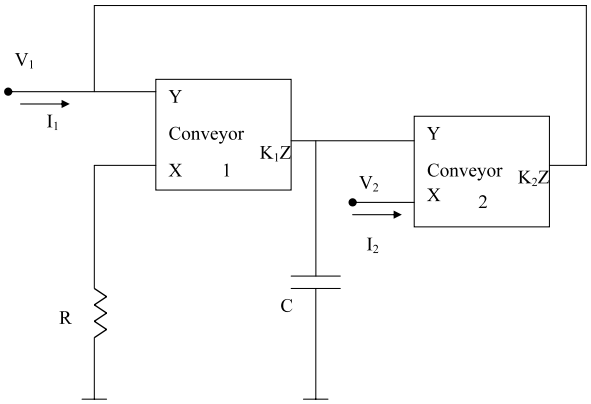

Fig. 2 Generalized conveyor realization of type 1a L-R mutator

Table 1 The family of type 1a L-R mutator circuits generated from Fig. 2

1a L-R mutator	a_1	K_1	a_2	K_2	Conveyor 1	Conveyor 2	Reference
A-1	+	+	+	−	CCII+	CCII−	11
A-2	+	−	−	−	CCII−	ICCII−	New
A-3	−	−	+	−	ICCII−	CCII−	New
A-4	−	+	−	−	ICCII+	ICCII−	New

2.1 Type 1a L-R Mutator

The type 1 L-R mutator referred to in this paper as type 1a L-R mutator is defined by the following transmission matrix [3]:

$$T_{\text{1a L-R}} = \begin{bmatrix} s\tau & 0 \\ 0 & 1 \end{bmatrix}. \tag{2}$$

Figure 2 represents a generalized conveyor realization for the type 1a L-R mutator obtained from realization 4 given in [11] where $\tau = CR$.

The necessary conditions for the generalized circuit of Fig. 2 to realize (2) are given by

$$K_2 = -1 \quad \text{and} \quad a_1 a_2 K_1 = 1. \tag{3}$$

The above conditions are satisfied by four alternative CCII and ICCII circuits three of them are new as given in Table 1. The parasitic resistance R_{X1} can be absorbed in R and the load resistor can absorb R_{X2}. The parasitic capacitance C_{Z1} can be absorbed in C.

The only parasitic element affecting the circuit operation is C_{Z2}.

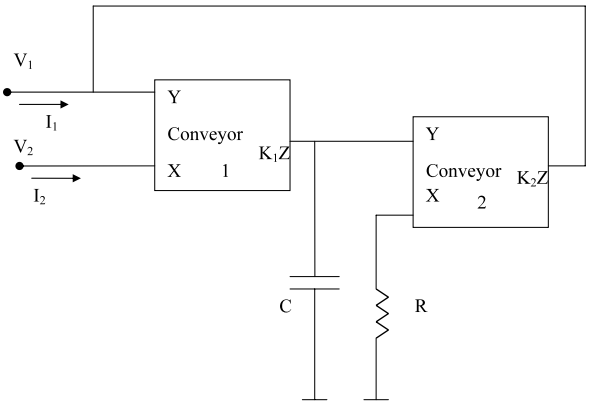

Fig. 3 Generalized conveyor realization of type 1b L-R mutator

Table 2 The family of type 1b L-R mutator circuits generated from Fig. 3

1b L-R mutator	a_1	K_1	a_2	K_2	Conveyor 1	Conveyor 2	Reference
A-1	+	+	+	−	CCII+	CCII−	13
A-2	+	−	+	+	CCII−	CCII+	New
A-3	+	+	−	+	CCII+	ICCII+	New
A-4	+	−	−	−	CCII−	ICCII−	New

2.2 Type 1b L-R Mutator

The type 1b L-R mutator was introduced in [13] and is defined by the following transmission matrix:

$$T_{\text{1b L-R}} = \begin{bmatrix} 1 & 0 \\ 0 & \frac{1}{s\tau} \end{bmatrix}. \tag{4}$$

Figure 3 represents a generalized conveyor realization for the type 1b L-R mutator given in [13], where $\tau = CR$.

The necessary conditions for the generalized circuit of Fig. 3 to realize (4) are given by

$$a_1 = 1 \quad \text{and} \quad K_1 K_2 a_2 = -1. \tag{5}$$

The above conditions are satisfied by four alternative CCII and ICCII circuits three of them are new as given in Table 2.

The only parasitic element affecting the circuit operation is C_{Z2}.

3 Converter Type L-C Mutators

It is well known that there are three types of L-C mutators [11, 12] that belong to the generalized impedance converter (GIC). In this section the basic definitions are reviewed and new realizations are introduced using CCII and ICCII.

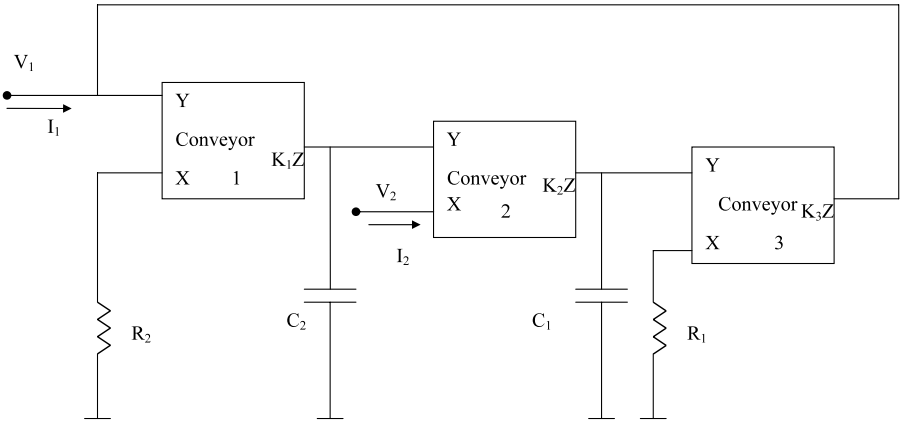

Fig. 4 Generalized conveyor realization of type 2a L-C mutator

3.1 Type 2a L-C Mutator

The type 2 L-C mutator referred to in this paper as type 2a L-C mutator is defined by the following transmission matrix [3]:

$$T_{2a\ \text{L-C}} = \begin{bmatrix} s\tau_2 & 0 \\ 0 & \frac{1}{s\tau_1} \end{bmatrix}. \tag{6}$$

Figure 4 represents a generalized conveyor realization for the type 2a L-C mutator obtained from realization 2 given in [11] where $\tau_i = C_i R_i$ $(i = 1, 2)$

The necessary conditions for the generalized circuit of Fig. 4 to realize (6) are given by

$$a_3 K_2 K_3 = -1 \quad \text{and} \quad a_1 a_2 K_1 = 1. \tag{7}$$

The above conditions are satisfied by sixteen alternative CCII and ICCII circuits one of them was reported before in [11] the others are new as given in Table 3.

The parasitic elements affecting the circuit are R_{X2} and C_{Z3}.

3.2 Type 2b L-C Mutator

The type 2b L-C mutator is a special case from the VGIC and is defined by the following transmission matrix [12]:

$$T_{2b\ \text{L-C}} = \begin{bmatrix} \tau_1 \tau_2 s^2 & 0 \\ 0 & 1 \end{bmatrix}. \tag{8}$$

Figure 5 represents a generalized conveyor realization for the type 2b L-C mutator obtained from realization 2 given in [12]; where $\tau_i = C_i R_i$ $(i = 1, 2)$.

The necessary conditions for the generalized circuit of Fig. 5 to realize (8) are given by

$$K_3 = -1 \quad \text{and} \quad a_1 a_2 a_3 K_1 K_2 = 1. \tag{9}$$

Table 3 The family of type 2a L-C mutator circuits generated from Fig. 4

2a L-C mutator	a_1	K_1	a_2	K_2	a_3	K_3	Conveyor 1	Conveyor 2	Conveyor 3	Reference
A-1	+	+	+	−	+	+	CCII+	CCII−	CCII+	New
A-2	+	+	+	+	+	−	CCII+	CCII+	CCII−	11
A-3	+	+	+	+	−	+	CCII+	CCII+	ICCII+	New
A-4	+	+	+	−	−	−	CCII+	CCII−	ICCII−	New
A-5	−	−	+	−	+	+	ICCII−	CCII−	CCII+	New
A-6	−	−	+	+	+	−	ICCII−	CCII+	CCII−	New
A-7	−	−	+	+	−	+	ICCII−	CCII+	ICCII+	New
A-8	−	−	+	−	−	−	ICCII−	CCII−	ICCII−	New
A-9	−	+	−	−	+	+	ICCII+	ICCII−	CCII+	New
A-10	−	+	−	+	+	−	ICCII+	ICCII+	CCII−	New
A-11	−	+	−	+	−	+	ICCII+	ICCII+	ICCII+	New
A-12	−	+	−	−	−	−	ICCII+	ICCII−	ICCII−	New
A-13	+	−	−	−	+	+	CCII−	ICCII−	CCII+	New
A-14	+	−	−	+	+	−	CCII−	ICCII+	CCII−	New
A-15	+	−	−	+	−	+	CCII−	ICCII+	ICCII+	New
A-16	+	−	−	−	−	−	CCII−	ICCII−	ICCII−	New

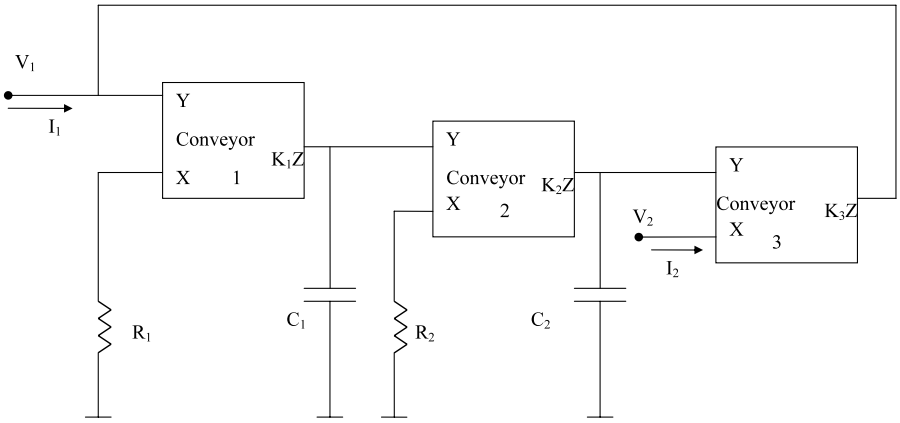

Fig. 5 Generalized conveyor realization of type 2b L-C mutator

The above conditions are satisfied by sixteen alternative CCII and ICCII circuits one of them was reported before in [12] the others are new as shown in Table 4.

The parasitic elements affecting the circuit are R_{X3} and C_{Z3}.

3.3 Type 2c L-C Mutator

The type 2c L-C mutator is a special case from the current generalized impedance converter (CGIC) [1] and is defined by the following transmission matrix [12]:

$$T_{2c\ \text{L-C}} = \begin{bmatrix} 1 & 0 \\ 0 & \frac{1}{\tau_1 \tau_2 s^2} \end{bmatrix}. \tag{10}$$

Table 4 The family of type 2b L-C mutator circuits generated from Fig. 5

2b L-C mutator	a_1	K_1	a_2	K_2	a_3	K_3	Conveyor 1	Conveyor 2	Conveyor 3	Reference
A-1	+	+	+	+	+	−	CCII+	CCII+	CCII−	12
A-2	+	−	+	−	+	−	CCII−	CCII−	CCII−	New
A-3	−	−	+	+	+	−	ICCII−	CCII+	CCII−	New
A-4	+	+	−	−	+	−	CCII+	ICCII−	CCII−	New
A-5	−	+	−	+	+	−	ICCII+	ICCII+	CCII−	New
A-6	−	+	+	−	+	−	ICCII+	CCII−	CCII−	New
A-7	−	+	+	+	−	−	ICCII+	CCII+	ICCII−	New
A-8	+	−	−	+	+	−	CCII−	ICCII+	CCII−	New
A-9	+	−	+	+	−	−	CCII−	CCII+	ICCII−	New
A-10	+	+	−	+	−	−	CCII+	ICCII+	ICCII−	New
A-11	+	+	+	−	−	−	CCII+	CCII−	ICCII−	New
A-12	−	−	−	−	+	−	ICCII−	ICCII−	CCII−	New
A-13	−	−	−	+	−	−	ICCII−	ICCII+	ICCII−	New
A-14	−	−	+	−	−	−	ICCII−	CCII−	ICCII−	New
A-15	−	+	−	−	−	−	ICCII+	ICCII−	ICCII−	New
A-16	+	−	−	−	−	−	CCII−	ICCII−	ICCII−	New

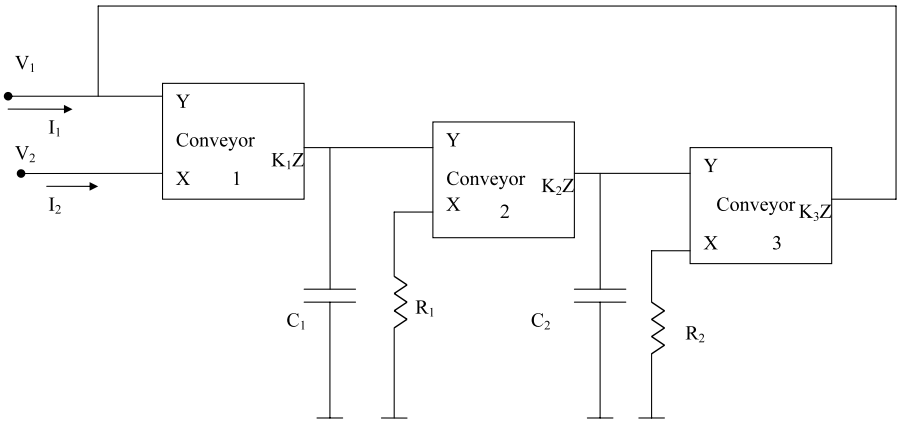

Fig. 6 Generalized conveyor realization of type 2c L-C mutator

Figure 6 represents a generalized conveyor realization for the type 2c L-C mutator obtained from realization 2 given in [12]; where $\tau_i = C_i R_i$ $(i = 1, 2)$.

The necessary conditions for the generalized circuit of Fig. 6 to realize (10) are given by

$$a_1 = 1 \quad \text{and} \quad a_2 a_3 K_1 K_2 K_3 = -1. \tag{11}$$

The above conditions are satisfied by sixteen alternative CCII and ICCII circuits one of them was reported before in [12] and seven of them are reported in [8] and the other eight are new as shown in Table 5.

The parasitic elements affecting the circuit are R_{X1} and C_{Z3}.

Table 5 The family of type 2c L-C mutator circuits generated from Fig. 6

2c L-C mutator	a_1	K_1	a_2	K_2	a_3	K_3	Conveyor 1	Conveyor 2	Conveyor 3	Reference
A-1	+	−	+	+	+	+	CCII−	CCII+	CCII+	12, 8
A-2	+	+	−	+	+	+	CCII+	ICCII+	CCII+	New
A-3	+	+	+	−	+	+	CCII+	CCII−	CCII+	New
A-4	+	+	+	+	−	+	CCII+	CCII+	ICCII+	New
A-5	+	+	+	+	+	−	CCII+	CCII+	CCII−	New
A-6	+	−	+	−	−	+	CCII−	CCII−	ICCII+	8
A-7	+	+	+	−	−	−	CCII+	CCII−	ICCII−	New
A-8	+	−	+	+	−	−	CCII−	CCII+	ICCII−	8
A-9	+	−	−	+	+	−	CCII−	ICCII+	CCII−	8
A-10	+	−	−	−	+	+	CCII−	ICCII−	CCII+	8
A-11	+	+	−	+	−	−	CCII+	ICCII+	ICCII−	New
A-12	+	+	−	−	+	−	CCII+	ICCII−	CCII−	New
A-13	+	+	−	−	−	+	CCII+	ICCII−	ICCII+	New
A-14	+	−	+	−	+	−	CCII−	CCII−	CCII−	8
A-15	+	−	−	+	−	+	CCII−	ICCII+	ICCII+	8
A-16	+	−	−	−	−	−	CCII−	ICCII−	ICCII−	8

4 Inverter Type L-R Mutators

There are two types of L-R mutators [11, 13] that belong to generalized impedance inverter (GII) type. In this section the basic definitions are reviewed and new realizations are introduced using CCII and ICCII.

4.1 Type 2a L-R Mutator

The type 2 L-R mutator referred to in this paper as type 2a L-R mutator was introduced in [3] and defined by

$$T_{2\text{a L-R}} = \begin{bmatrix} 0 & sCR_1R_2 \\ \frac{1}{R} & 0 \end{bmatrix}. \tag{12}$$

Figure 7 represents a generalized conveyor realization for type 2a L-R mutator obtained from realization 2 given in [11].

The necessary conditions for the generalized circuit of Fig. 7 to realize (12) are given by

$$a_3K_3 = -1 \quad \text{and} \quad a_1a_2K_1K_2 = 1. \tag{13}$$

The above conditions are satisfied by sixteen alternative CCII and ICCII circuits one of them was reported before in [11] and the other fifteen are new as shown in Table 6.

The parasitic elements affecting the circuit are C_{Z2} and C_{Z3}.

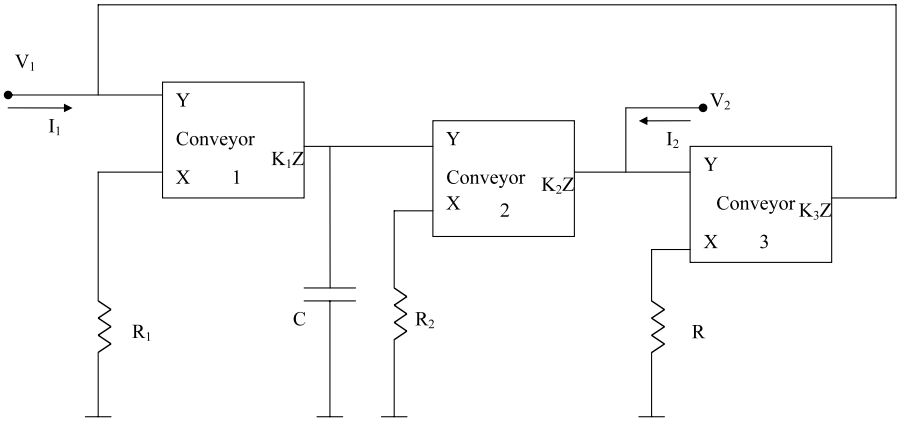

Fig. 7 Generalized conveyor realization of type 2a L-R mutator

Table 6 The family of type 2a L-R mutator circuits generated from Fig. 7

2a L-R mutator	a_1	K_1	a_2	K_2	a_3	K_3	Conveyor 1	Conveyor 2	Conveyor 3	Reference
A-1	+	+	+	+	+	−	CCII+	CCII+	CCII−	11
A-2	+	−	+	−	+	−	CCII−	CCII−	CCII−	New
A-3	−	+	−	+	+	−	ICCII+	ICCII+	CCII−	New
A-4	−	−	+	+	+	−	ICCII−	CCII+	CCII−	New
A-5	−	+	+	−	+	−	ICCII+	CCII−	CCII−	New
A-6	+	−	−	+	+	−	CCII−	ICCII+	CCII−	New
A-7	+	+	−	−	+	−	CCII+	ICCII−	CCII−	New
A-8	−	−	−	−	+	−	ICCII−	ICCII−	CCII−	New
A-9	+	+	+	+	−	+	CCII+	CCII+	ICCII+	New
A-10	+	−	+	−	−	+	CCII−	CCII−	ICCII+	New
A-11	−	+	−	+	−	+	ICCII+	ICCII+	ICCII+	New
A-12	−	−	+	+	−	+	ICCII−	CCII+	ICCII+	New
A-13	−	+	+	−	−	+	ICCII+	CCII−	ICCII+	New
A-14	+	−	−	+	−	+	CCII−	ICCII+	ICCII+	New
A-15	+	+	−	−	−	+	CCII+	ICCII−	ICCII+	New
A-16	−	−	−	−	−	+	ICCII−	ICCII−	ICCII+	New

4.2 Type 2b L-R Mutator

The type 2b L-R mutator was introduced in [13] and defined by

$$T_{\text{2b L-R}} = \begin{bmatrix} 0 & R \\ \frac{1}{sCR_1R_2} & 0 \end{bmatrix}. \tag{14}$$

Figure 8 represents a generalized conveyor realization for type 2b L-R mutator obtained from realization 1 given in [13].

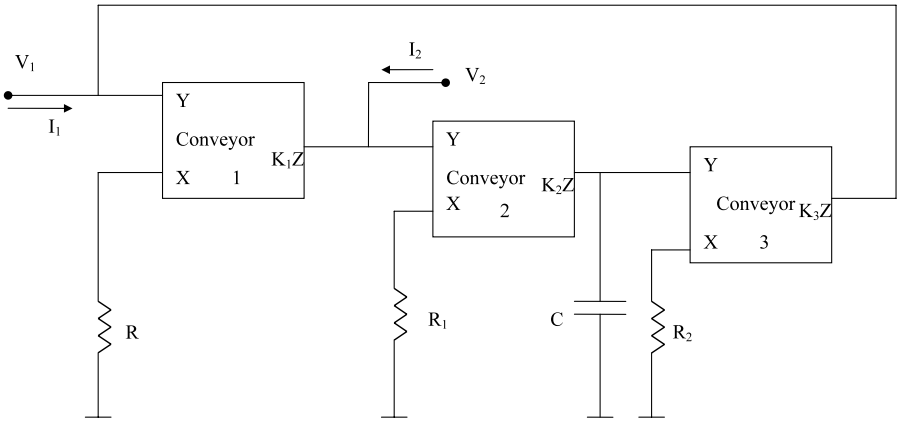

Fig. 8 Generalized conveyor realization of type 2b L-R mutator

Table 7 The family of type 2b L-R mutator circuits generated from Fig. 8

2b L-R mutator	a_1	K_1	a_2	K_2	a_3	K_3	Conveyor 1	Conveyor 2	Conveyor 3	Reference
A-1	+	+	+	−	+	+	CCII+	CCII−	CCII+	New
A-2	+	+	+	+	+	−	CCII+	CCII+	CCII−	13
A-3	+	+	−	+	+	+	CCII+	ICCII+	CCII+	New
A-4	+	+	+	+	−	+	CCII+	CCII+	ICCII+	New
A-5	+	+	+	−	−	−	CCII+	CCII−	ICCII−	New
A-6	+	+	−	+	−	−	CCII+	ICCII+	ICCII−	New
A-7	+	+	−	−	+	−	CCII+	ICCII−	CCII−	New
A-8	+	+	−	−	−	+	CCII+	ICCII−	ICCII+	New
A-9	−	−	+	−	+	+	ICCII−	CCII−	CCII+	New
A-10	−	−	+	+	+	−	ICCII−	CCII+	CCII−	New
A-11	−	−	−	+	+	+	ICCII−	ICCII+	CCII+	New
A-12	−	−	+	+	−	+	ICCII−	CCII+	ICCII+	New
A-13	−	−	+	−	−	−	ICCII−	CCII−	ICCII−	New
A-14	−	−	−	+	−	−	ICCII−	ICCII+	ICCII−	New
A-15	−	−	−	−	+	−	ICCII−	ICCII−	CCII−	New
A-16	−	−	−	−	−	+	ICCII−	ICCII−	ICCII+	New

The necessary conditions for the generalized circuit of Fig. 8 to realize (14) are given by

$$a_1K_1 = 1 \quad \text{and} \quad a_2a_3K_2K_3 = -1. \tag{15}$$

The above conditions are satisfied by sixteen alternative CCII and ICCII circuits one of them was reported before in [13] and the other fifteen are new as shown in Table 7.

The parasitic elements affecting the circuit are C_{Z1} and C_{Z3}.

5 Conclusions

Several realizations of L-R and L-C mutators using CCII and ICCII are given. It should be noted that for the type 2c L-C mutator eight pathological realizations were recently generated [8] using nodal admittance matrix expansion (NAM) [5–7].

It should also be noted that the realizations given in this paper are referred to as realizations-A , since there are alternative realizations defined as realizations-B not included in this paper in which capacitors are connected to the X terminals of the conveyors. The realizations-B has limited frequency response since the parasitic R_X acts in series with the capacitor C and affects the circuit performance.

It should be noted that the gyrator is also known as type 1 L-C mutator and it belong to the GII and the generation of alternative realizations using NAM expansion was given in detail in [9].

It is also worth noting that the second type of the gyrator with its two ports taken as the X terminals of the conveyors given in [4, 15], were published originally in [11] using CCII+ and CCII− and defined as realization 1 of the type 1 L-C mutator. Of course realization 2 of the type 1 L-C mutator as given in [11] is the well known gyrator with its two ports taken as the Y terminals of the two conveyors namely, CCII+ and CCII−.

It is recommended that the CCII and ICCII to be used in the mutator realizations must have low parasitic capacitance C_Z and low parasitic resistance R_X.

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