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Generalized immittance inverters and their realizations

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New realizations of the positive generalized immittance inverter are given using the current conveyor as the active element. Two classes of the inverter are introduced here, with two network models given for each case. It is seen that Chua's types 2L-R, 2C-R and 1L-C mutators, as well as type 2bL-R mutator defined by the author, can be realized as special cases. Application of the inverter in the realization of a one-port frequency-dependent resistor is discussed.

1. Introduction

The generalized immittance converter circuits and their realizations using the current conveyor (CC) as the active building block was discussed in detail (Soliman 1972). Many realizations for the impedance inverter using the transistor or the operational amplifier as the active element are available in the literature (Daniels 1969, Mitra 1969, Pauker 1970).

Simulation of special types of the generalized inverter using the CC as the active element are well known, for example, Chua's (1968) types 2L-R, 2C-R and 1L-C mutators are realized by Smith and Sedra (1970). Also type 1bL-R mutator was defined and realized by the author (Soliman 1973).

In this paper the realization of two classes of the generalized positive immittance inverter (GPII), using the CC as the active element, are given. The advantage of these realizations is that all circuit components are grounded. The use of the given inverters in realizing a one-port frequency-dependent resistor is also discussed.

2. Definitions

2.1. *The current conveyor CC*

The CC is a grounded three-port network having the following instantaneous port relations :

$$\begin{bmatrix} i_b \\ v_a \\ i_c \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 1 \end{bmatrix} \begin{bmatrix} v_b \\ i_a \\ v_c \end{bmatrix} \qquad (1)$$

The conveyor will include a positive sign if $i_c = i_a$ and a negative sign if $i_c = -i_a$ as shown in Fig. 1 (*a*) and (*b*) respectively (Sedra and Smith 1970).

2.2. *The generalized immittance inverter GII*

The GII is an active two-port which presents to the input port an impedance $= Ks^r/Z_L$ when the output port is terminated by Z_L, where r is a

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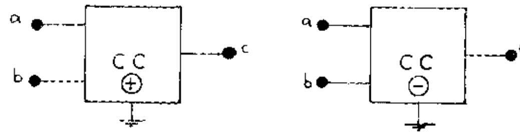


Figure 1. Symbolic representation of the CC.

positive integer, negative integer or zero, K is a constant which may be positive or negative. Accordingly the inverter is defined as a positive or a negative inverter. The transmission matrix for the generalized positive immittance inverter GPII is

$$[T(s)] = \begin{bmatrix} 0 & \pm as^n \\ \pm bs^m & 0 \end{bmatrix} \tag{2}$$

For the generalized negative immittance inverter GNII the transmission matrix is

$$[T(s)] = \begin{bmatrix} 0 & \pm as^n \\ \mp bs^m & 0 \end{bmatrix} \tag{3}$$

where $r = n - m$ (n and m are integers or zero), $K = \pm a/b$, the positive sign is for the GPII, whereas the negative sign is for the GNII (a and b are positive numbers).

In this paper two classes of the GPII are defined and realized using the CC as the active device.

3. Glass 1 GPII

The class 1 GPII is defined by the following transmission matrix :

$$[T]_1 = \begin{bmatrix} 0 & Z \\ \dfrac{Z_2 Z_4}{Z_1 Z_3 Z_5} & 0 \end{bmatrix} \tag{4}$$

That is, it can realize a family of inverters having $n = 0$ or -1, and m can be in the range $-2 \leqslant m \leqslant 3$. Two network models for realizing this inverter are given in Fig. 2. In the first realization the two-port currents are the independent variables, whereas in the second realization the voltages are the independent variables.

Table 1 shows how to choose the circuit components to realize the 12 possible types of inverters that belong to class 1 GPII. It is noted that

(*a*) Inverter No. 2 is Soliman's type 2bL-R mutator.
(*b*) Inverter No. 3 is Chua's type 1L-C mutator (gyrator).
(*c*) Inverter No. 4 is Chua's type 2C-R mutator.
(*d*) Inverters 7, 8 and 9 realize new types of mutators as shown in Table 1.

It is seen that Chua's type 2L-R mutator cannot be realized from class 1 GPII.

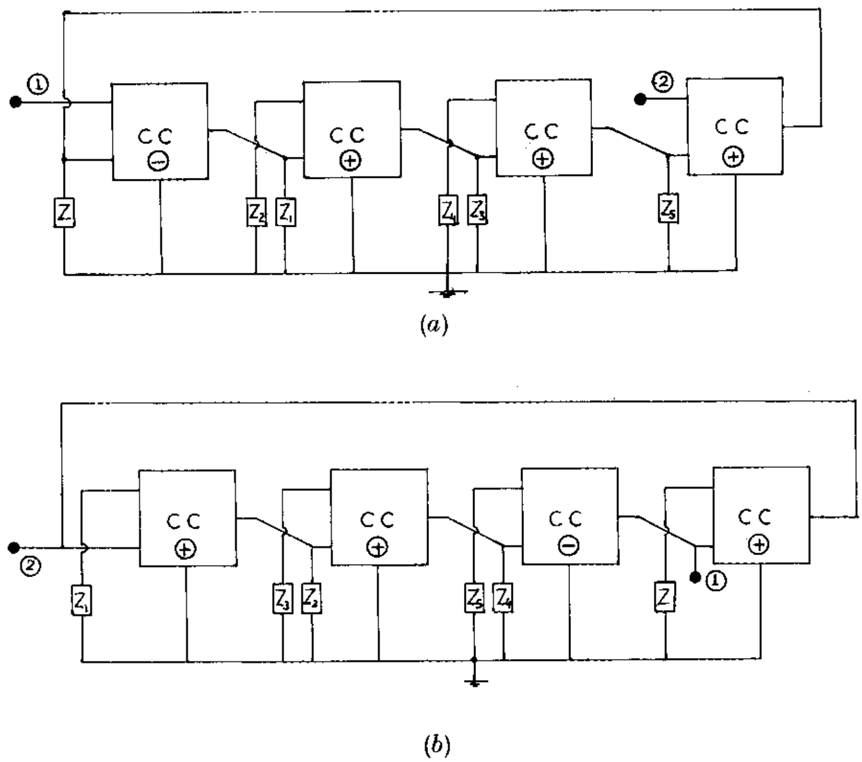


Figure 2. Realizations of the GPII having port relations

$$V_1 = -ZI_2, \quad I_1 = \frac{Z_2 Z_4}{Z_1 Z_3 Z_5} V_2$$

(*a*) Realization 1, I_1 and I_2 are independent variables. (*b*) Realization 2, V_1 and V_2 are independent variables.

No.	n	m	Z	Z_1	Z_2	Z_3	Z_4	Z_5	Mutator type
1	0	−2	R	R	C	R	C	R	
2	0	−1	R	R	C	R	R	R	2bL-R
3	0	0	R	R	R	R	R	R	1L-C
4	0	1	R	C	R	R	R	R	2C-R
5	0	2	R	C	R	C	R	R	
6	0	3	R	C	R	C	R	C	
7	−1	−2	C	R	C	R	C	R	2cL-R
8	−1	−1	C	R	C	R	R	R	1cL-C
9	−1	0	C	R	R	R	R	R	2cC-R
10	−1	1	C	C	R	R	R	R	
11	−1	2	C	C	R	C	R	R	
12	−1	3	C	C	R	C	R	C	

Table 1. Different types of the GPII that can be generated from class 1 GPII.

4. Class 2 GPII

Here the transmission matrix is given by

$$[T]_2 = \begin{bmatrix} 0 & \dfrac{ZZ_5}{Z_4} \\ \dfrac{Z_2}{Z_1 Z_3} & 0 \end{bmatrix} \tag{5}$$

The parameters n and m that are realizable, using this GPII, are in the range $-2 \leqslant n \leqslant 1$, $-1 \leqslant m \leqslant 2$, that is, 16 different inverters can be generated from class 2 GPII as seen in table 2.

It is noted that inverter No. 2 in the table is Chua's type 2L-R mutator. New mutators are also generated from this GPII, as demonstrated in Table 2. The inverters from No. 5 to No. 12 are realizable also from class 1 GPII, as can be observed by comparing Tables 1 and 2.

No.	n	m	Z	Z_1	Z_2	Z_3	Z_4	Z_5	Mutator type
1	1	−1	R	R	C	R	C	R	
2	1	0	R	R	R	R	C	R	2L-R
3	1	1	R	C	R	R	C	R	1bL-C
4	1	2	R	C	R	C	C	R	2bC-R
5	0	−1	R	R	C	R	R	R	2bL-R
6	0	0	R	R	R	R	R	R	1L-C
7	0	1	R	C	R	R	R	R	2C-R
8	0	2	R	C	R	C	R	R	
9	−1	−1	C	R	C	R	R	R	1cL-C
10	−1	0	C	R	R	R	R	R	2cC-R
11	−1	1	C	C	R	R	R	R	
12	−1	2	C	C	R	C	R	R	
13	−2	−1	C	R	C	R	R	C	2dC-R
14	−2	0	C	R	R	R	R	C	
15	−2	1	C	C	R	R	R	C	
16	−2	2	C	C	R	C	R	C	

Table 2. Different types of the GPII that can be generated from class 2 GPII.

5. Simulation of a one-port frequency-dependent resistor

The frequency-dependent negative resistance FDNR, which is defined by

$$Z(s) = D/s^2 \tag{6}$$

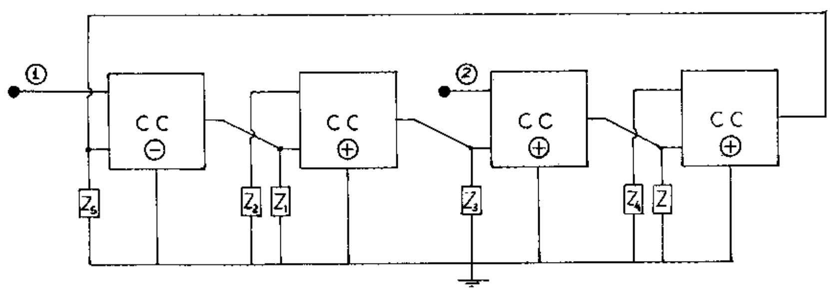
is a very useful circuit element in active network synthesis. Some realizations for this active one-port network using the positive immittance converter, are available (Bruton 1969). Here a realization, using the GPII, is given.

Consider the GPII in Fig. 2 or Fig. 3; if port 2 is terminated in an impedance Z_L, the input impedance seen at port 1 is given by

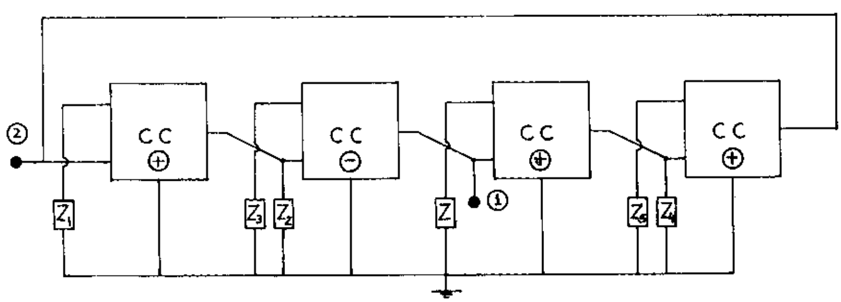
$$Z = \frac{ZZ_1Z_3Z_5}{Z_LZ_2Z_4} \tag{7}$$

thus a FDNR is realized if any two from Z, Z_1, Z_3 and Z_5 are capacitors and all other impedances are resistors.

It is also possible to realize a frequency-dependent positive resistor FDPR of the form $Z(s) = K/s^4$, this new active network may have some applications in active network synthesis.



(*a*)



(*b*)

Figure 3. Realizations of the GPII having port relations

$$V_1 = -\frac{ZZ_5}{Z_4} I_2, \quad I_1 = \frac{Z_2}{Z_1Z_3} V_2$$

(*a*) Realization 1, I_1 and I_2 are independent variables. (*b*) Realization 2, V_1 and V_2 are independent variables.

6. Conclusions

A unified approach to the realization of generalized positive immittance inverters GPII are given using the current conveyor as the active element. The advantage of these inverters is that all passive circuit components are earthed. New mutators are generated from these inverters. The minimum number of capacitors needed to realize any inverter is $|n| + |m|$. The models for the GNII can be obtained by slight modification of the given circuits.

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