INT. J. ELECTRONICS, 1972, VOL. 32, NO. 6, 673–679

New generalized-immittance converter circuits obtained by using the current conveyor†

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[Received 5 July 1971]

The realization of special types of the generalized-immittance converters will be given here using the second-generation current conveyor. Of particular interest in this paper is the new realization of the voltage generalized-immittance converter having conversion immittance function proportional to s^2. It will be seen that two realizations exist for each converter.

1. Introduction

A special type of the current generalized-immittance converter was recently introduced, and used in one of the recent and most attractive RC active network synthesis procedures (Antoniou 1970). Antoniou (1970) used the operational amplifier as the active building block in the realization of the current generalized-immittance converter.

In a recent publication, Sedra and Smith (1970) introduced the second-generation current conveyor (will be abbreviated here as the current conveyor CC) and used it in the realization of some active network elements. The current conveyor is a versatile building block, as it can be used as a current summer, current differentiator, current integrator, current amplifier, etc.

In this paper the simulation of special types of both voltage and current generalized-immittance converters using the current conveyor will be given.

2. Definitions

2.1. *The current conveyor CC*

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

$$\begin{bmatrix} i_b \\ v_a \\ i_c \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} v_b \\ i_a \\ v_c \end{bmatrix}. \tag{1}$$

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

2.2. *Generalized-immittance converters GIC*

A generalized-immittance converter (Antoniou 1969) is an active two-port

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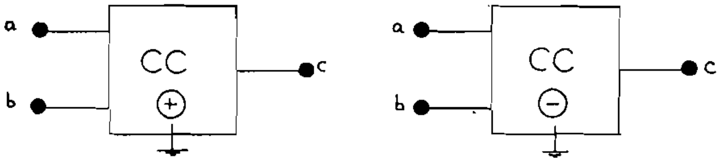
† Communicated by the Author.

Fig. 1



(a) (b)

Symbolic representation of the current conveyor.

network which presents to the input port an impedance $= \pm f(s) Z_L$ when the output is terminated by Z_L and $f(s)$ is known as the impedance conversion function, where s is the complex frequency variable. The converter will be referred to as positive (negative) if $Z_i = f(s) Z_L$ $(Z_i = -f(s) Z_L)$ and will be abbreviated PGIC (NGIC).

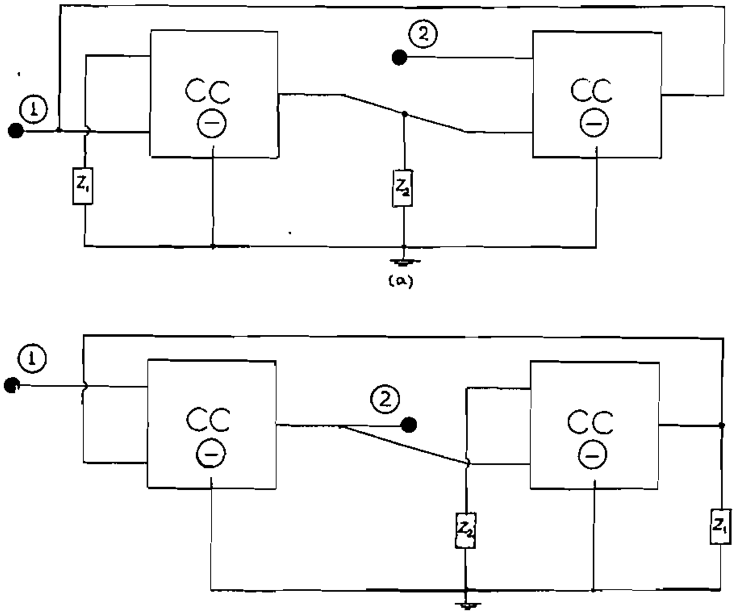
Two types of generalized-immittance converters exist :

(a) Voltage inversion type VGIC

The voltage inversion type generalized-immittance converter has a transmission matrix of the form

$$\underset{\text{VGIC}}{[T(s)]} = \begin{bmatrix} \pm f(s) & 0 \\ 0 & 1 \end{bmatrix}. \tag{2}$$

Fig. 2



(a)

(b)

Realizations of the VNIC having port relations

$$V_1 = -\frac{Z_1}{Z_2} V_2 \quad \text{and} \quad I_1 = -I_2,$$

(*b*) *Current inversion type CGIC*

Here the transmission matrix is

$$\underset{\text{CGIC}}{[T(s)]} = \begin{bmatrix} 1 & 0 \\ 0 & \pm\dfrac{1}{f(s)} \end{bmatrix}. \tag{3}$$

In this paper a special class of the generalized-immittance-converters having $f(s) = ks^{\pm n}$ ($n = 0, 1, 2, 3, \ldots$) will be realized using the current conveyor, and n will be referred to as the order of the converter.

3. Realization of the NIC having $n = \pm 1$ or 0

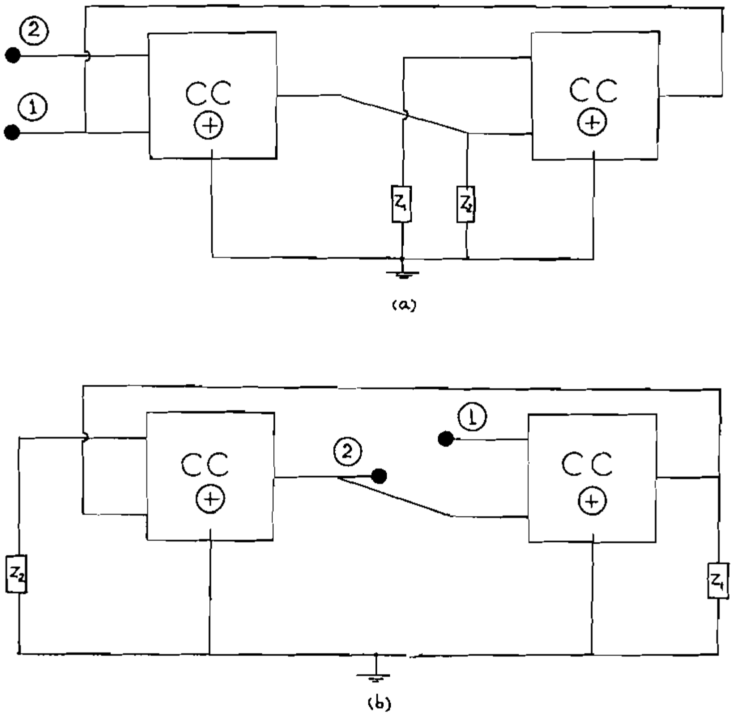
3.1. *Voltage negative immittance converters VNIC*

Figures 2 (*a*) and (*b*) realize the VNIC having the following port relations :

$$\begin{aligned} V_1 &= -\frac{Z_1}{Z_2} V_2, \\ I_1 &= -I_2. \end{aligned} \tag{4}$$

By using resistance (capacitance) as Z_1 and capacitance (resistance) as Z_2, $f(s) = ks$ ($f(s) = 1/ks$), and the VNIC having $n = 1$ (-1) is realized.

Fig. 3



Realizations of the CNIC having port relations.

$$V_1 = V_2 \quad \text{and} \quad I_1 = \frac{Z_2}{Z_1} I_2.$$

The VNIC having $n=0$ is of special interest and can be realized from the circuits in figs. 2 (*a*) and (*b*) if both Z_1 and Z_2 are resistances (capacitances). Of course, if $Z_1=Z_2$, the unit VNIC results.

3.2. *Current negative immittance converters CNIC*

Two different circuits are given in fig. 3, both having the port relations

$$\begin{aligned} V_1 &= V_2, \\ I_1 &= \frac{Z_2}{Z_1} I_2. \end{aligned} \tag{5}$$

Again, by properly choosing Z_1 and Z_2, CNIC having $n=\pm 1$ or 0 can be realized as special cases. It should also be noted here that all CC can be negative in these two realizations.

The realizations of the PIC having $n=\pm 1$ or 0, and using the current conveyor, are available in one of the references (Smith and Sedra 1970) by noting that :

(*a*) The VPIC having $n=+1$ is an L–R mutator, type 1.
(*b*) The VPIC having $n=0$ is a voltage scalar.
(*c*) The CPIC having $n=-1$ is a C–R mutator, type 1.
(*d*) The CPIC having $n=0$ is a current scalar.

By interchanging R and C in (*a*) and (*c*) above, VPIC having $n=-1$ and CPIC having $n=+1$, respectively, will result.

4. Realization of higher-orders VPIC

Figures 4 (*a*) and (*b*) realize the VPIC having the following port relations :

$$\begin{aligned} V_1 &= \frac{Z_1 Z_3}{Z_2 Z_4} V_2, \\ I_1 &= -I_2. \end{aligned} \tag{6}$$

Using resistances (capacitances) as Z_1 and Z_3, and capacitances (resistances) as Z_2 and Z_4, $f(s)=ks^2$ ($f(s)=1/ks^2$).

This circuit can be used to realize the frequency dependent negative resistance FDNR having impedance $=as^2$, where a is positive constant $=kR$, by terminating port 2 in a resistance R (Bruton 1969 and Antoniou 1970).

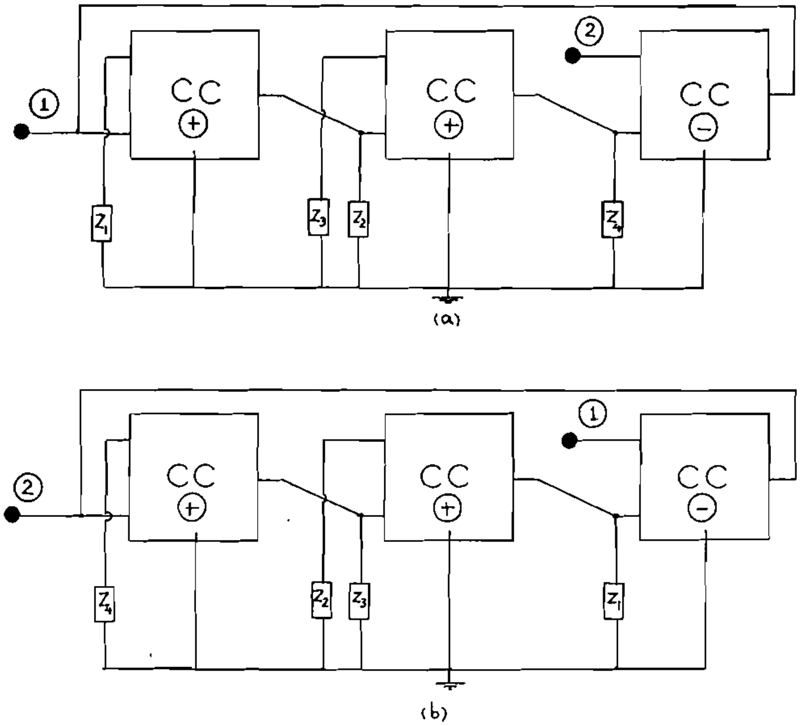
This network also realizes variable inductors by terminating the output port by a fixed capacitor, and varying either R_1 or R_3 or both (Chua 1968) also (Sedra and Smith 1970).

Figure (5) realizes the VPIC having the following port relations :

$$\begin{aligned} V_1 &= \frac{Z_1 Z_3 Z_5}{Z_2 Z_4 Z_6} V_2, \\ I_1 &= -I_2. \end{aligned} \tag{7}$$

Using resistances as Z_1, Z_3 and Z_5 and capacitances as Z_2, Z_4 and Z_6, $f(s)=ks^3$, and realization of FNDR having impedance $=bs^3$, where b is a positive constant,

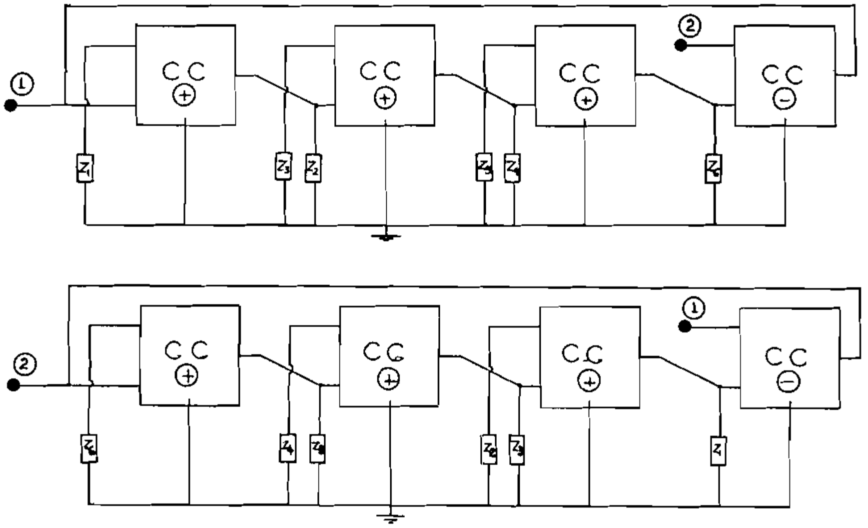
Fig. 4



Realizations of the VPIC having port relations

$$V_1=\left(\frac{Z_1Z_3}{Z_2Z_4}\right)V_2 \quad \text{and} \quad I_1=-I_2.$$

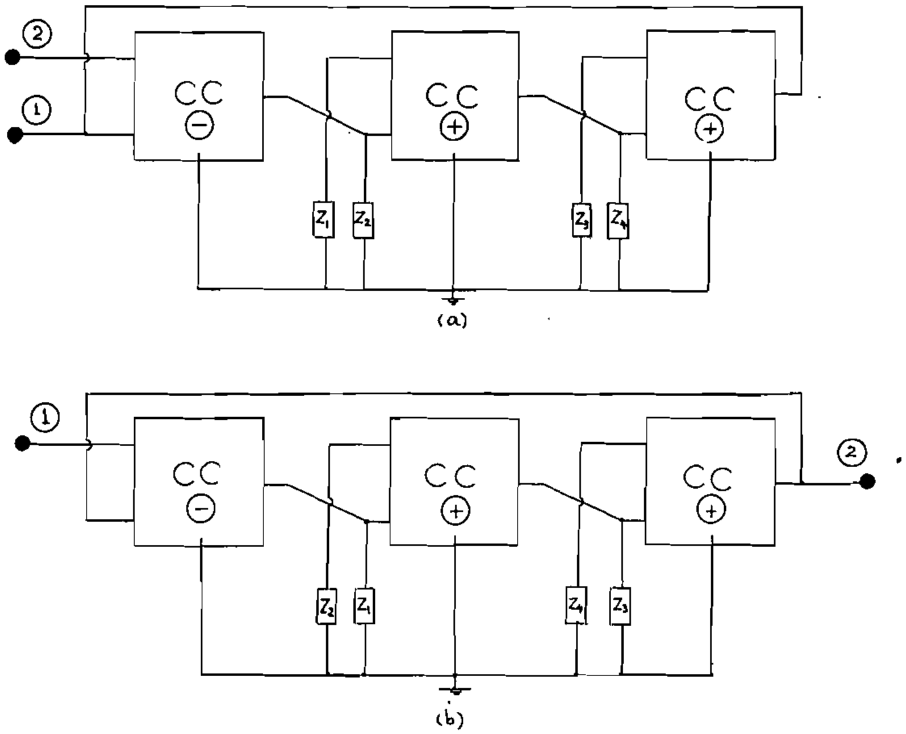
Fig. 5



Realizations of the VPIC having port relations

$$V_1=\left(\frac{Z_1Z_3Z_5}{Z_2Z_4Z_6}\right)V_2 \quad \text{and} \quad I_1=-I_2.$$

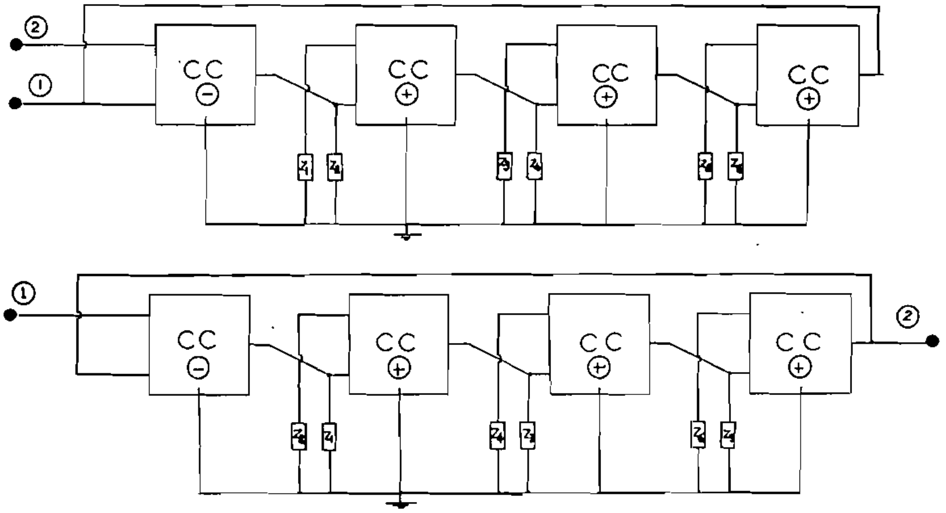
Fig. 6



Realizations of the CPIC having port relations

$$V_1 = V_2 \quad \text{and} \quad I_1 = -\left(\frac{Z_2Z_4}{Z_1Z_3}\right) I_2.$$

Fig. 7



Realizations of the CPIC having port relations

$$V_1 = V_2 \quad \text{and} \quad I_1 = -\left(\frac{Z_2Z_4Z_6}{Z_1Z_3Z_5}\right) I_2.$$

is possible by terminating the output port in a resistance. This new active two-terminal element may have some interesting applications in active network synthesis.

Higher-order VPIC can be realized by cascading successive sections.

5. Realization of higher-order CPIC

Figures 6 (*a*) and (*b*) realize the CPIC having the port relations

$$V_1 = V_2,$$

$$I_1 = -\frac{Z_2 Z_4}{Z_1 Z_3} I_2, \tag{8}$$

which is the same as that realized by Antoniou (1970) using two operational amplifiers.

Similarly fig. (7) realizes CPIC having $n = \pm 3$ by properly choosing Z_i $(1 \leqslant i \leqslant 6)$.

Higher-order CPIC can be simulated by cascading successive sections.

In a similar manner higher-order voltage or current NIC can be simulated using the current conveyor.

6. Conclusions

A unified approach to the realization of special types of voltage and current generalized-immittance converters using the current conveyor was given. Of particular interest in this paper is the realization of the voltage positive-immittance converter having conversion admittance proportional to s^2; this new active two-port network, as well as the current positive immittance converter, were introduced by Antoniou (1969), and the latter was realized by Antoniou (1969) using operational amplifiers; however, no realization is available to the author's knowledge for the first. Also the new generalized-immittance converters introduced in this paper, and having conversion impedance (admittance) proportional to s^n where n is an integer, may be of useful importance in active network synthesis. It can be easily seen that the number of current conveyors required to realize this type of GIC equals $n+1$.

References

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