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Ahmed M. Soliman [a];Ramy A. Saad [b]
[a] Electronics and Communications Engineering Department, Cairo University, Giza, Egypt [b] Analog & Mixed-Signal Center (AMSC), Texas A&M University, College Station, TX, USA

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Generation of second generation current conveyor (CCII) family from inverting second generation current conveyor (ICCII) family

Ahmed M. Soliman[a]* and Ramy A. Saad[b]

[a]*Electronics and Communications Engineering Department, Cairo University, Giza 12613, Egypt;* [b]*Analog & Mixed-Signal Center (AMSC), Texas A&M University, College Station, TX 77843-3128, USA*

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Based on the nodal admittance matrix (NAM) representation of the voltage mirror (VM)–norator pair and considering the case of an inverting second generation current conveyor (ICCII−), it is found that the second generation current conveyor (CCII−) is a special case from the generalised ICCII−. Considering the NAM of the VM–current mirror pair, it is also found that the CCII+ is a special case from the generalised ICCII+.

Keywords: current conveyor CCII; inverting CCII; pathological voltage mirror; pathological current mirror; nullator; norator

1. Introduction

The second generation current conveyor (CCII) shown symbolically and defined in Figure 1a is a universal building block that was introduced by Sedra and Smith (1970). The positive sign of I_Z applies to the CCII+ and the negative sign is for the CCII−. The CCII family members are the CCII+ and the CCII−. The CCII− can practically be realised from two CCIIs+ in several configurations (Awad and Soliman 2000). There is no nullator norator representation of the CCII+ unless resistors are used (Svoboda 1989). On the other hand, the nullator norator representation of the CCII− as a nullor with a common terminal between nullator and norator is shown in Figure 1b (Svoboda 1989; Sedra, Roberts and Gohh 1990). The ICCII is also a universal building block that was introduced by Awad and Soliman (1999) and is shown symbolically and defined in Figure 1c. The ICCII family members are the ICCII+ and the ICCII−. The nullor representation of the CCII− shown in Figure 1b cannot lead to pathological representation of the ICCII−. It is of interest to see how the pathological representation of the CCII− is related to that of the ICCII−. Using the pathological voltage mirror (VM) and the norator pair, it is shown that the pathological representation of the CCII− can be obtained from the generalised pathological representation of the ICCII−. Similarly, using the pathological VM and current mirror (CM) pair it is shown that the pathological representation of the CCII+ can be obtained from the generalised pathological representation of the ICCII+.

*Corresponding author. Email: asoliman@ieee.org

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2. General nodal admittance matrix stamp for the voltage mirror–norator pair

Consider the general five terminal floating VM–norator pairs in Figure 2, consisting of a floating VM (Awad and Soliman 2002) whose terminals are connected to nodes a, b and c and a norator whose terminals are connected to nodes d and e and defined by:

$$V_{ac} = -V_{bc} \tag{1a}$$

$$I_a = I_b = 0 \tag{1b}$$

$$V_d \text{ and } V_e \text{ are arbitrary} \tag{1c}$$

$$I_d = -I_e \text{ and they are also arbitrary.} \tag{1d}$$

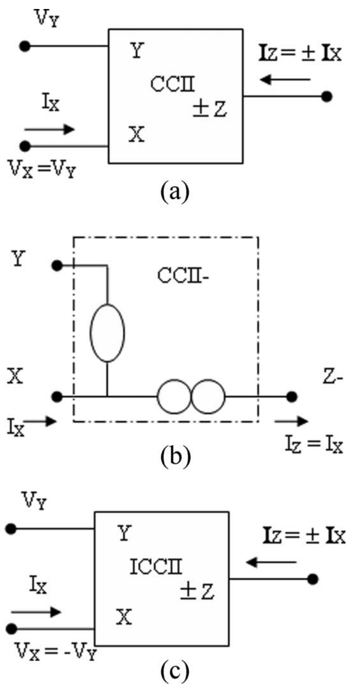


Figure 1. (a) Circuit symbol of CCII. (b) CCII− realised as a nullor with a common terminal. (c) Circuit symbol of ICCII.

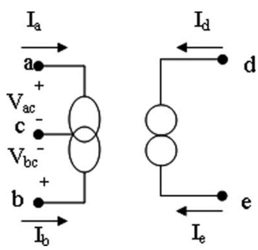


Figure 2. Floating VM–norator pair.

Node c is the reference node for the VM. This five-terminal floating VM–norator pair can be represented using two dependent sources when their gains tend to infinity. Each of the two dependent sources describes the relation between the voltage at one port in the VM element and the current at one port in the norator. Since the considered synthesis framework uses the admittance matrices and the voltage-controlled current source (VCCS) is the only dependent source that possesses an admittance matrix (Haigh, Clarke and Radmore 2006), the VM–norator pair in Figure 2 should be described in terms of a VCCS for which the transconductance gains tend to infinity. Hence, the admittance matrix stamp for the representation of the five-terminal floating VM–norator pair whose terminals are connected as in Figure 2 can be considered as that for the VCCS-based ideal model in Figure 3, with the transconductance gain of every VCCS being G_{mi} and taken to a limit of infinity. This VCCS-based ideal model can be entered into the nodal admittance matrix (NAM) in the following form:

$$\begin{array}{c} \\ d \\ \\ e \end{array}\begin{array}{c} \begin{array}{ccc} a & b & c \end{array} \\ \begin{bmatrix} G_{mi} & G_{mi} & -2G_{mi} \\ & & \\ -G_{mi} & -G_{mi} & 2G_{mi} \end{bmatrix} \end{array} \tag{2}$$

where G_{mi} is taken to a limit of infinity. Then, rows d and e of the NAM equation set will have the form:

$$\begin{bmatrix} I_d \\ \\ Ie \end{bmatrix} = \begin{bmatrix} G_{mi} & G_{mi} & -2G_{mi} \\ & & \\ -G_{mi} & -G_{mi} & 2G_{mi} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ Vc \end{bmatrix} + \begin{bmatrix} \text{finite terms} \\ \\ \text{finite terms} \end{bmatrix} \tag{3}$$

where $G_{mi} \to \infty$. It is known that in order to preserve the finiteness of an equation containing a parameter that tends to infinity, the whole equation must be divided by this parameter before taking the limit (Haigh et al. 2006), provided that the limit applies to the whole equation and not to that parameter alone. In order to apply this principle to the above equations corresponding to rows d and e of the NAM

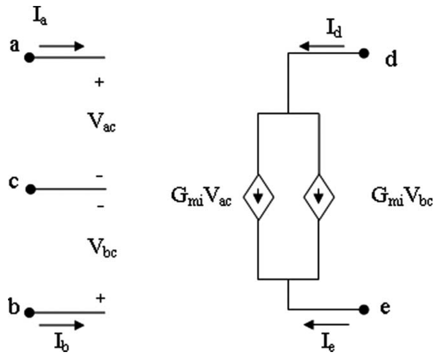


Figure 3. VCCS-based model for the floating VM–norator pair.

equation set, these equations are divided by G_{mi} and limit of G_{mi} when it tends to infinity is taken for both sides of each row. Thus, rows d and e are described by:

$$\begin{bmatrix} \frac{I_d}{G_{mi}} \\ \frac{I_e}{G_{mi}} \end{bmatrix} = \begin{bmatrix} 1 & 1 & -2 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} + \begin{bmatrix} \frac{\text{finite terms}}{G_{mi}} \\ \frac{\text{finite terms}}{G_{mi}} \end{bmatrix} \quad (4)$$

where $G_{mi} \to \infty$. When the limit is taken, dependent current terms on the left-hand side (LHS) and finite terms on the right-hand side (RHS) will vanish as described by:

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & 1 & -2 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix}. \quad (5)$$

The two rows in the NAM equation set corresponding to the norator nodes yield the same relation between independent voltage variables

$$V_a + V_b - 2V_c = 0 \to V_{ac} = -V_{bc} \quad (6)$$

Since the floating VM–norator pair description in Equation (5) has no matrix entries for rows a and b, therefore

$$I_a = I_b = I_c = 0 \quad (7)$$

The similarity between the coefficients of rows d and e in Equation (3) imposes the constraint that the current entering the norator at node d is equal to that leaving it at node e. Equation (3) represents Kirchoff's current law (KCL) at each of nodes d and e; however, the values of the currents at the terminals of the norator are unconstrained. Since the columns corresponding to nodes d and e do not exist in the description of Equation (5), there are no constraints on the terminal voltages of the norator. Thus, the NAM description in Equation (2) with $G_{mi} \to \infty$ imposes finite relationships between the nodal voltages and currents which correctly describe a floating VM–norator pair connected as shown in Figure 2.

As explained by Haigh et al. (2006) and Haigh and Radmore (2006), the nullor elements can be represented in the NAM using infinity-variables. In this notation, the variables in the NAM that are taken to an infinite limit are written as ∞_i, where ∞_i indicates that the limit is taken to infinity and i refers to the active element represented by the nullor.

On applying this infinity-variables notation to the floating VM–norator pair description, Equation (2) becomes:

$$\begin{array}{c} \\ d \\ \\ e \end{array} \begin{array}{c} \begin{array}{ccc} a & b & c \end{array} \\ \begin{bmatrix} \infty_i & \infty_i & -2\infty_i \\ & & \\ -\infty_i & -\infty_i & 2\infty_i \end{bmatrix} \end{array}. \quad (8)$$

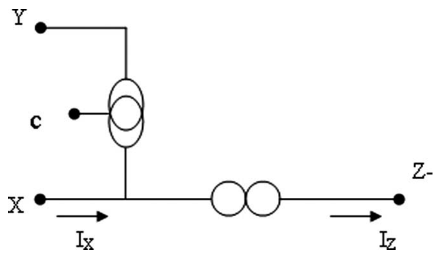


Figure 4. VM and norator with a common terminal (generalised ICCII−).

The presence of a norator between the two nodes d and e causes the infinity-variables in the two NAM rows corresponding to nodes d and e to have equal coefficients with opposite signs.

The set of infinity-variables describing the VM–norator pair in Equation (8) indicates that the floating VM (Saad and Soliman 2008a,b), whose two ports are connected between each of the nodes a and b and the floating reference node c, causes the infinity-variables in the two columns a and b to be equal and to have the same signs, while the coefficients of the infinity-variables in column c are double those in each of columns a and b and have opposite signs. Similarly, the norator whose two ports are connected between each of the nodes d and e causes the infinity-variables in the two rows d and e to be equal and to have opposite signs.

2.1. *NAM stamp for ICCII−*

The NAM of the four-terminal generalised ICCII− shown in Figure 4 is given by:

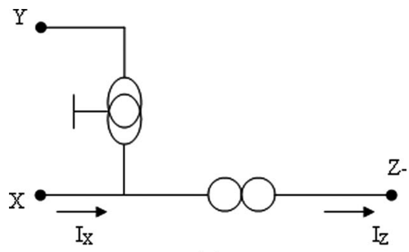
$$\begin{array}{c} \\ X \\ \\ Z- \end{array} \begin{array}{c} \begin{array}{ccc} X & Y & \mathrm{c} \end{array} \\ \begin{bmatrix} \infty_i & \infty_i & -2\infty_i \\ & & \\ -\infty_i & -\infty_i & 2\infty_i \end{bmatrix} \end{array}. \tag{9}$$

Upon grounding terminal c in Figure 4, thereby removing the third column of Equation (9), the NAM of the ICCII− shown in Figure 5a is obtained and is given by:

$$\begin{array}{c} \\ X \\ Z_i \end{array} \begin{array}{c} \begin{array}{cc} X & Y \end{array} \\ \begin{bmatrix} \infty_i & \infty \\ -\infty_i & -\infty_i \end{bmatrix} \end{array}. \tag{10}$$

2.2. *NAM stamp for CCII−*

If terminal c is connected to terminal Y in Figure 4, and thereby adding the terms in their corresponding columns, the resulting NAM will be:



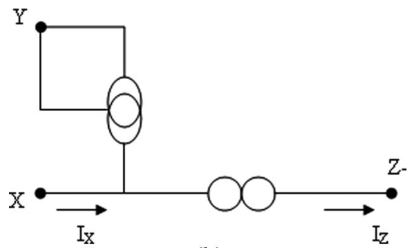


Figure 5. (a) ICCII− realised as a VM and a norator with a common terminal. (b) CCII− realised from a VM and a norator with a common terminal.

$$\begin{array}{c} \\ X \\ Z_i \end{array}\begin{array}{c} \begin{array}{cc} X & \quad Y \end{array} \\ \begin{bmatrix} \infty_i & -\infty_i \\ -\infty_i & \infty_i \end{bmatrix} \end{array}. \tag{11}$$

The above equation represents the NAM of a CCII− shown in Figure 5b.

In a similar way, the CCII+ can be obtained as a special case from the generalised ICCII+ as illustrated in the following section.

3. General NAM stamp for the VM–CM pair

The VM–CM pair shown in Figure 6a consists of a floating VM whose terminals are connected to nodes a, b and c, and a grounded CM whose terminals are connected to nodes d and e and defined by:

$$V_{ac} = -V_{bc} \tag{12a}$$

$$I_a = I_b = I_c = 0 \tag{12b}$$

$$V_d \text{ and } V_e \text{ are arbitrary} \tag{12c}$$

$$I_d = I_e \text{ and they are also arbitrary} \tag{12d}$$

Node c is the reference node for the VM. The VM–CM pair can be represented using four VCCSs when their gains tend to infinity. Each of the four dependent sources describes the relation between the voltage at one port in the VM element and

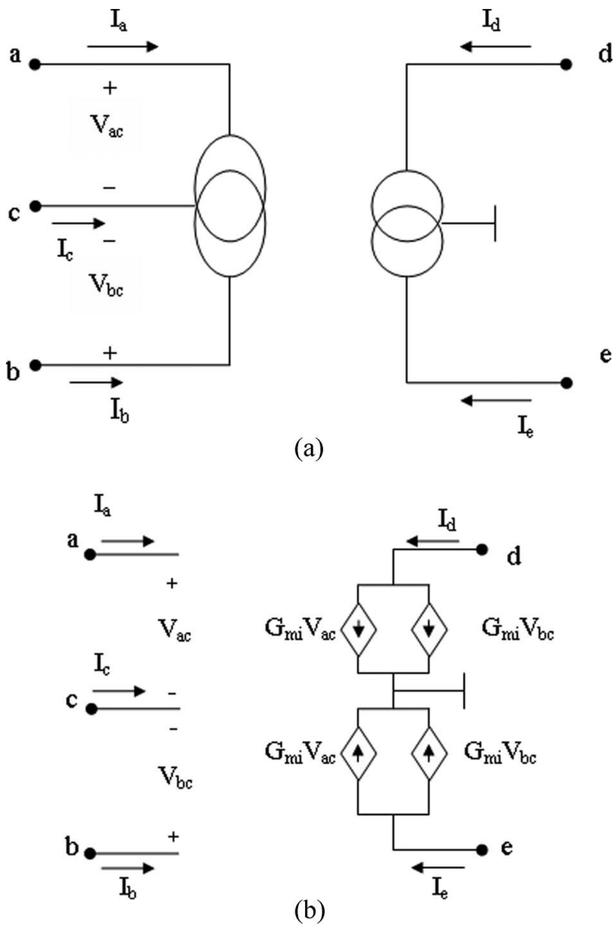


Figure 6. (a) Floating VM-grounded CM pair. (b) VCCS-based model for the floating VM–CM pair.

the current at one port in the CM. Figure 6b represents the VCCS-based ideal model and is represented by the following NAM equation:

$$\begin{array}{c} \\ d \\ \\ e \end{array}\begin{array}{c} \begin{array}{ccc} a & b & c \end{array} \\ \begin{bmatrix} G_{mi} & G_{mi} & -2G_{mi} \\ & & \\ G_{mi} & G_{mi} & -2G_{mi} \end{bmatrix} \end{array}. \tag{13}$$

G_{mi} is taken to a limit of infinity. Then, rows d and e of the NAM equation set will have the form:

$$\begin{bmatrix} I_d \\ \\ I_e \end{bmatrix} = \begin{bmatrix} G_{mi} & G_{mi} & -2G_{mi} \\ & & \\ G_{mi} & G_{mi} & -2G_{mi} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} + \begin{bmatrix} \text{finite terms} \\ \\ \text{finite terms} \end{bmatrix}. \tag{14}$$

The rows d and e are described by:

$$\begin{bmatrix} \frac{I_d}{G_{mi}} \\ \frac{I_e}{G_{mi}} \end{bmatrix} = \begin{bmatrix} 1 & 1 & -2 \\ 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} + \begin{bmatrix} \frac{\text{finite terms}}{G_{mi}} \\ \frac{\text{finite terms}}{G_{mi}} \end{bmatrix}. \tag{15}$$

When the limit is taken, the dependent current terms on the RHS and the finite terms on the LHS will vanish as described by:

$$\begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & 1 & -2 \\ 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix}. \tag{16}$$

The two rows in the NAM equation set corresponding to the CM terminals yield the same relation between independent voltage variables

$$V_a + V_b - 2V_c = 0 \rightarrow V_{ac} = -V_{bc}. \tag{17}$$

Since the VM–CM pair description in Equation (16) has no matrix entries for rows a and b, therefore

$$I_a = I_b = I_c = 0. \tag{18}$$

Equation (15) indicates KCL at each of nodes d and e; however, the values of the currents at the terminals of the CM are unconstrained. Since the columns corresponding to nodes d and e do not exist in the description of Equation (16), there are no constraints on the terminal voltages of the CM. Thus, the NAM description in Equation (13) with $G_{mi} \rightarrow \infty$ imposes finite relationships between the nodal voltages and currents which correctly describe a floating VM-grounded CM pair connected as shown in Figure 6a.

Upon applying the infinity-variables notation to the floating VM-grounded CM pair description, Equation (13) becomes:

$$\begin{array}{c c} & \begin{array}{ccc} a & b & c \end{array} \\ \begin{array}{c} d \\ e \end{array} & \begin{bmatrix} \infty_i & \infty_i & -2\infty_i \\ \infty_i & \infty_i & -2\infty_i \end{bmatrix} \end{array}. \tag{19}$$

The set of infinity-variables describing the VM–CM pair in Equation (19) indicates that the floating VM whose two ports are connected between each of the nodes a and b and the floating reference node c causes the infinity-variables in the two columns a and b to be equal and have the same signs, while the coefficients of the infinity-variables in column c are double those in each of columns a and b and have opposite signs. Similarly, the CM whose two ports are connected between each of the nodes d and e causes the infinity-variables in the two rows d and e to be equal and have the same signs.

The NAM of the generalised ICCII+ shown in Figure 7a is given by:

$$\begin{array}{c} \\ X \\ \\ Z+ \end{array} \begin{array}{c} \begin{array}{ccc} X & Y & c \end{array} \\ \begin{bmatrix} \infty_i & \infty_i & -2\infty_i \\ & & \\ \infty_i & \infty_i & -2\infty_i \end{bmatrix} \end{array}. \tag{20}$$

Upon grounding terminal c thereby removing the third column of Equation (20), the NAM of ICCII+ shown in Figure 7b is given by:

$$\begin{array}{c} \\ X \\ Z+ \end{array} \begin{array}{c} \begin{array}{cc} X & Y \end{array} \\ \begin{bmatrix} \infty_i & \infty_i \\ \infty_i & \infty_i \end{bmatrix} \end{array}. \tag{21}$$

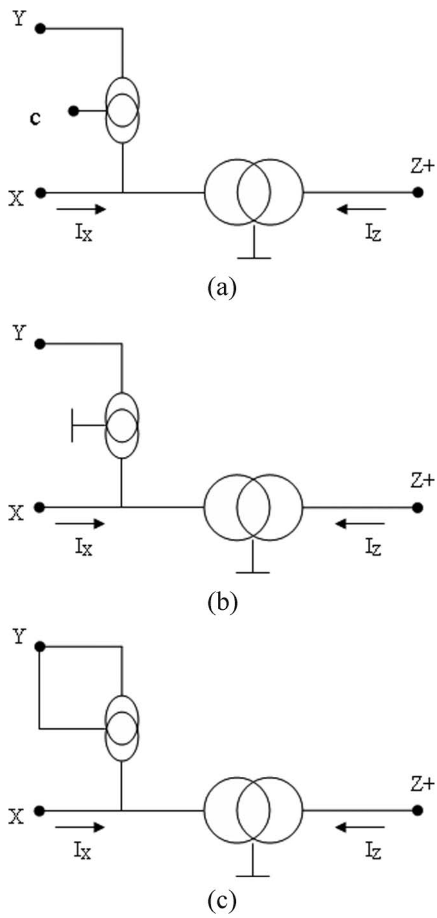


Figure 7. (a) The generalised ICCII+. (b) The ICCII+ realised from a VM–CM pair with a common terminal. (c) The CCII+ realised from a VM–CM pair with a common terminal.

If terminal c is connected to terminal Y in Figure 7c and thereby adding the terms in their corresponding columns, the resulting NAM will be:

$$\begin{array}{c} \\ X \\ Z+ \end{array}\begin{array}{c} \begin{array}{cc} X & Y \end{array} \\ \begin{bmatrix} \infty_i & -\infty_i \\ \infty_i & -\infty_i \end{bmatrix} \end{array}. \tag{22}$$

The above equation represents the NAM of a CCII+.

4. Conclusions

It is shown that the NAM of the CCII− is obtained from the generalised four-terminal ICCII− by connecting the common terminal c to Y. It is also shown that the NAM of the CCII+ is obtained from the generalised four-terminal ICCII+ by connecting the common terminal c to Y. This provides an alternative proof to that given by Saad and Soliman (2008b) that the VM with one of its terminals connected to the common terminal realises a nullator.

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References

Awad, I.A., and Soliman, A.M. (1999), 'Inverting Second Generation Current Conveyors: The Missing Building Blocks, CMOS Realizations and Applications', *International Journal of Electronics*, 86, 413–432.

Awad, I.A., and Soliman, A.M. (2000), 'A New Approach to Obtain Alternative Active Building Blocks Realizations Based on Their Ideal Representations', *Frequenz*, 54, 290–299.

Awad, I.A., and Soliman, A.M. (2002), 'On the Voltage Mirrors and the Current Mirrors', *Analog Integrated Circuits and Signal Processing*, 32, 79–81.

Haigh, D.G., Clarke, T.J.W., and Radmore, P.M. (2006), 'Symbolic Framework for Linear Active Circuits Based on Port Equivalence Using Limit Variables', *IEEE Transactions on Circuits Systems – I*, 53, 2011–2024.

Haigh, D.G., and Radmore, P.M. (2006), 'Admittance Matrix Models for the Nullor Using Limit Variables and Their Application to Circuit Design', *IEEE Transactions on Circuits Systems – I*, 53, 2214–2223.

Saad, R.A., and Soliman, A.M. (2008a), 'Use of Mirror Elements in the Active Device Synthesis by Admittance Matrix Expansion', *IEEE Transactions on Circuits Systems – I*, 55, 2726–2735.

Saad, R.A., and Soliman, A.M. (2008b), 'A New Approach for Using the Pathological Mirror Elements in the Ideal Representation of Active Devices', *International Journal on Circuit Theory and Applications*, DOI: 10.1002/cta.534.

Sedra, A.S., Roberts, G.W., and Gohh, F. (1990), 'The Current Conveyor: History, Progress and New Results', *IEE Proceedings Part G*, 137, 78–87.

Sedra, A.S., and Smith, K.C. (1970), 'A Second Generation Current Conveyor and Its Applications', *IEEE Transactions on Circuit Theory*, 17, 132–133.

Svoboda, J.A. (1989), 'Current Conveyors, Operational Amplifiers and Nullors', *IEE Proceedings Part G*, 136, 317–322.