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DIGITAL FILTER REALIZATION USING CURRENT CONVEYOR

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Abstract - By using the concept of current conveyor, new 1st order and 2nd order digital filter sections are developed. These are then used as building blocks in a cascade synthesis. The proposed synthesis yields digital Equivalent of 1st order all-pass filter and general 2nd order filter structure.

Keywords- Current Conveyor, wave equations, serial adaptor, parallel adaptor, all-pass filters., voltage source.

I. INTRODUCTION

Two types of digital-filters synthesis procedures have been proposed in recent years. Direct procedures in which the discrete-time transfer function is realized directly as cascade, canonic, parallel or ladder structure and the indirect procedures in which an LC filter satisfying the desired specifications is simulated by employing the wave characterization [5-9].

Present paper describes an alternative cascade but indirect synthesis. The basis of synthesis is an analogue configuration comprising resistors, capacitors and inductors and second generation positive current conveyors. In this paper we describe the synthesis of digital equivalent of first order all pass filter and general second order filter structure, which can be used in the design of digital equivalent of LPF, HPF and BPF.

Current conveyor

Current conveyor is a three port device (Fig. 1). Three generations of current conveyor are available but the second generation positive current conveyor is extensively used in the design of analogue filters [1-4]. The second generation positive current conveyor is characterized by.

$$\begin{bmatrix} I_x \\ V_y \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & +1 & 0 \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_z \end{bmatrix} \quad (1)$$

Digital equivalent of second generation positive current conveyor. An analogue port can be characterised by

$$\begin{aligned} A_k &= V_k + I_k / G_k \\ B_k &= V_k - I_k / G_k \end{aligned} \quad (2)$$

For $k=1,2,\dots,n$. where A_k and B_k are referred as the incident- and reflected-wave quantities respectively, G_k as the port conductance and V_k and I_k are the input voltage and input current at the port respectively. In the interconnection of n -ports, two interconnected ports must be assigned the same conductance so as to

maintain continuity in the wave flow. Otherwise G_k can be chosen arbitrarily.

On the basis of wave characterization, digital realizations are readily available for conductances, voltage sources and wire interconnections [5,6]. With $G_l = G_r$ in Figs. 3 and 4, $B_l=0$ in the first case and $A_l = K_r V_i$ in the second. Hence, a conductance reduces to a digital sink and a voltage source of a given intensity to a digital source of same intensity [5,6]. Similarly, for a three port wire interconnection of Fig. 4 the digital realization of Fig. 5 (known as parallel adaptor) can be obtained and the multiplier coefficient of parallel adaptor is given by

$$m_k = 2G_k / (G_1 + G_2 + G_3) \text{ for } k = 1, 2.$$

The same technique can be extended to second generation positive current conveyor of Fig. 1. As the second generation positive current conveyor has three set of equations as given by the matrix Eq.(1). By transforming variables A_k, B_k, V_k and I_k and then using Eq. (1) and (2), we can show that

$$B_x = 2A_y - A_x \quad (3)$$

$$B_y = A_y \quad (4)$$

$$B_z = A_z + (2R_z / R_x)(A_y - A_x) \quad (5)$$

$$\text{Define, } p = (2R_z / R_x)$$

With $R_x = 2R_z$, Eq.(5) simplifies to

$$B_z = A_z + A_y - A_x \quad (6)$$

And,

$$p = 1$$

Now, using the Eqs. (3), (4), (6), the digital realisation for the second generation positive current conveyor can be deduced as in Fig. 6.

II. DIGITAL REALIZATION OF ALL PASS FILTER

Considering the all pass filter of Fig. 7, having transfer function.

$$H(s) = \frac{(G - sC)}{(G + sC)} \quad (7)$$

The individual analogue components and the corresponding ports can be identified [14] as shown in Fig. 8. On assigning the port conductances as given below.

For the first current conveyor-

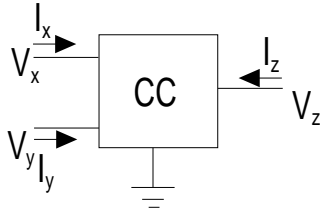


Fig.1. Current Conveyor

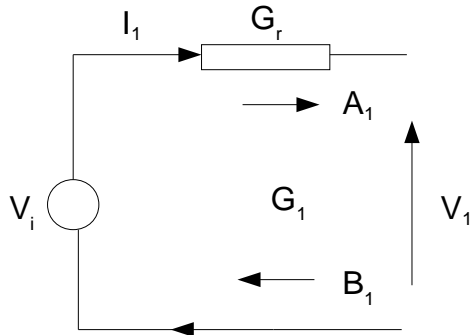


Fig.2. Conductance

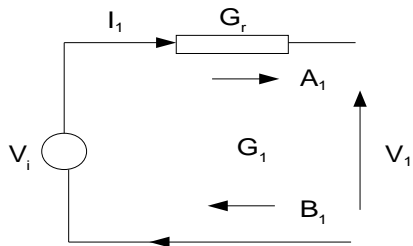


Fig.3. Voltage Source

$$G_{I_x} = G + \frac{4C}{T}, G_{I_y} = G, G_{I_z} = \frac{1}{2} \left(G + \frac{4C}{T} \right),$$

For the second current conveyor-

$$G_{2x} = 2 \left(G + \frac{2C}{T} \right), G_{2y} = \frac{1}{2} \left(G + \frac{8C}{T} \right), G_{2z} = \left(G + \frac{2C}{T} \right),$$

For the first parallel adaptor-

$$G_{11} = \frac{1}{2} \left(G + \frac{4C}{T} \right), G_{2y} = \frac{1}{2} \left(G + \frac{8C}{T} \right), G_{2z} = \frac{2C}{T}$$

And the multiplier constants are

$$m_1 = \frac{\left(G + \frac{4C}{T} \right)}{\left(G + \frac{8C}{T} \right)}, m_2 = 1,$$

For the second parallel adaptor-

$$G_{21} = G, G_{22} = G + \frac{2C}{T}, G_{23} = \frac{2C}{T},$$

And the multiplier constants are

$$m_1 = \frac{G}{\left(G + \frac{2C}{T} \right)}, m_2 = 1,$$

For the third parallel adaptor-

$$G_{31} = G + \frac{4C}{T}, G_{32} = 2 \left(G + \frac{2C}{T} \right), G_{33} = G,$$

And the multiplier constants are

$$m_1 = \frac{\left(G + \frac{4C}{T} \right)}{\left(G + \frac{2C}{T} \right)}, m_2 = 1,$$

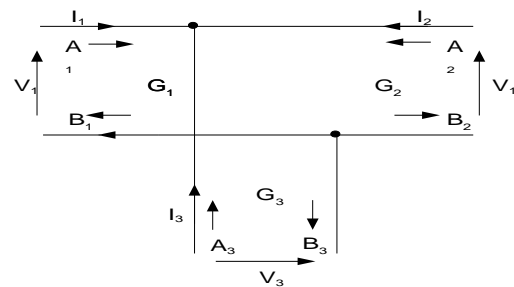


Fig.4. Parallel Adaptor

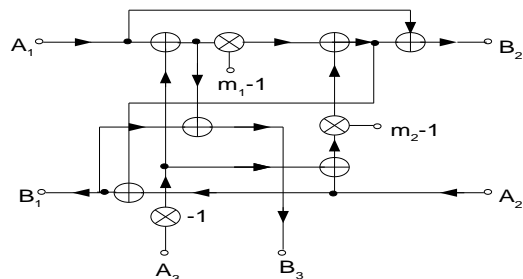


Fig.5 Digital equivalent of Parallel Adaptor

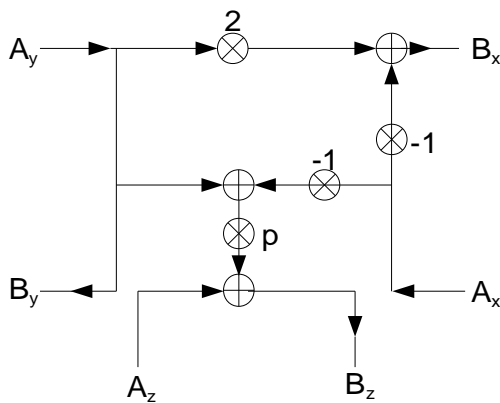


Fig.6 Digital equivalent of Current Conveyor

And now replacing the parallel wire interconnection and analogue current conveyor with its digital equivalent as given in Fig. 5 and 6, the first order digital all pass filter section is derived as shown in Fig. 9. The output proportional to V_o can be formed by using the adder at the output as shown in Fig. 8. The transfer function of the derived structure can be obtained from Eq. (2) and (8) as given by Eq. (10)

$$s \rightarrow \frac{2(z-1)}{T(z+1)} \quad (8)$$

$$H_D(z) = B_o / A_i = 2V_o / V_i \quad (9)$$

$$H_D(z) = [2H\{s\}]_{s \rightarrow \frac{2(z-1)}{T(z+1)}} \quad (10)$$

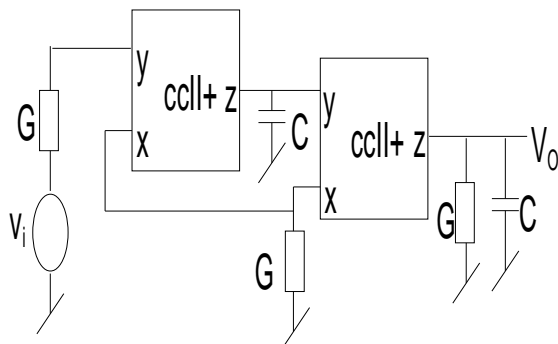


Fig.7. All pass filter of 1st order

III. DIGITAL REALIZATION OF GENERAL SECOND ORDER FILTER

We can also have the digital realization of second order filter of Fig. 10 using the method described above. The output is taken across the admittance G_4 as shown in Fig. 10,

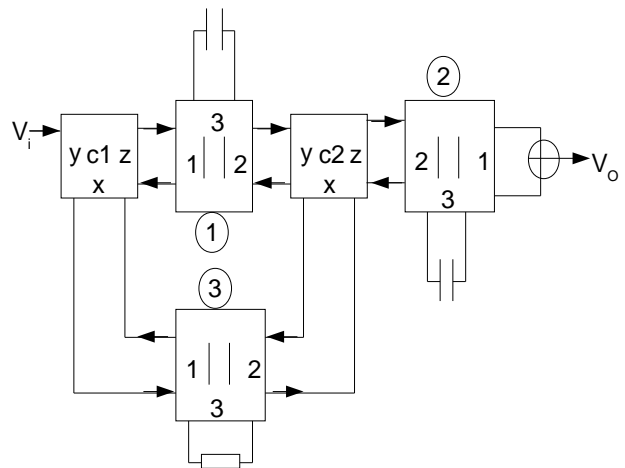


Fig.8. Port Identification of Fig.7

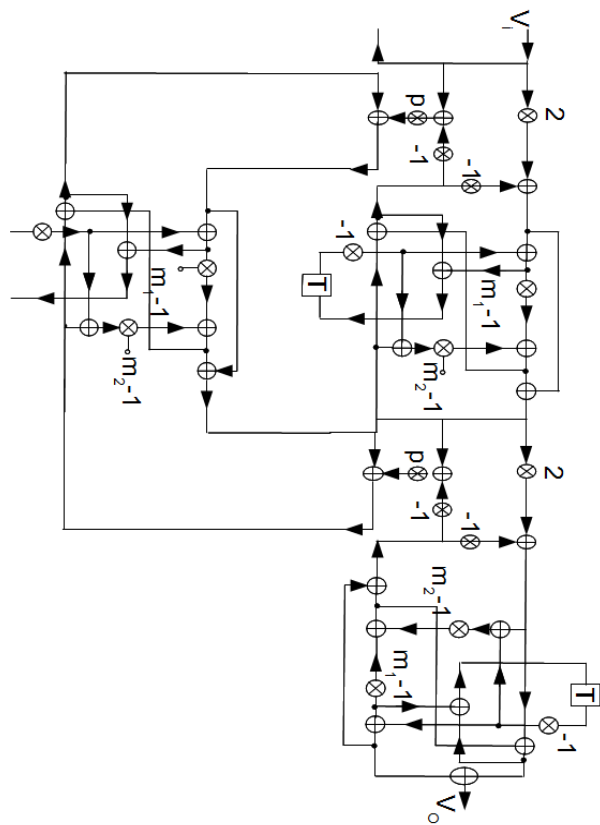


Fig.9. Digital equivalent of Fig.7

IV. DIGITAL REALIZATION OF GENERAL SECOND ORDER FILTER

We can also have the digital realization of second order filter of Fig. 10 using the method described above. The output is taken across the admittance G_4 as shown in Fig. 10, and the voltage V_o follows the voltage V_o as described by the Eq. (1). The transfer function of the filter structure in Fig. 10 is given by

$$H(s) = V'_o / V_i = Y_1 Y_2 / (Y_1 Y_3 + G_4 Y_5) \quad (11)$$

As the voltage V_o follows the voltage V'_o , so

$$H(s) = V'_o / V_i = V_o / V_i = Y_1 Y_2 / (Y_1 Y_3 + G_4 Y_5) \quad (12)$$

By selection of different components for Y_3, Y_2, Y_1 and Y_5 we can have LPF, BPF and HPF [12]. The individual analogue components and corresponding ports can be identified [14] as shown in Fig. 11, and the port conductance of various ports are given below.

For the first current conveyor

$$G_{1x} = Y_2 + (Y_5/2), G_{1y} = G, G_{1z} = \frac{1}{2} (Y_2 + (Y_5/2)),$$

For the second current conveyor

$$G_{2x} = G_4, G_{2y} = Y_3 + \frac{1}{2} (Y_2 + (Y_5/2)), G_{2z} = (G_4/2),$$

For the third current conveyor

$$G_{3x} = Y_5, G_{3y} = Y_1 + (G_4/2), G_{3z} = (Y_5/2),$$

For the first parallel adaptor

$$G_{11} = \frac{1}{2} (Y_2 + (Y_5/2)), G_{12} = Y_3 + \frac{1}{2} (Y_2 + (Y_5/2)), G_{13} = Y_3,$$

And the multiplier constants are

$$m_1 = \left(\frac{1}{2} (Y_2 + (Y_5/2)) \right) / \left(Y_3 + \frac{1}{2} (Y_2 + (Y_5/2)) \right),$$

$$m_2 = 1,$$

For the second parallel adaptor

$$G_{21} = (G_4/2), G_{22} = Y_1 + (G_4/2), G_{23} = Y_1,$$

And the multiplier constants are

$$m_1 = (G_4/2) / (Y_1 + (G_4/2)), m_2 = 1,$$

For the third parallel adaptor

$$G_{31} = (Y_5/2), G_{32} = Y_2 + (Y_5/2), G_{33} = (Y_5/2)$$

And the multiplier constants are

$$m_1 = (Y_5/2) / (Y_2 + (Y_5/2)), m_2 = 1,$$

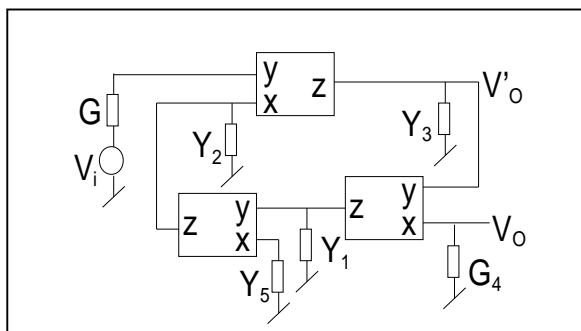


Fig.10. General second order filter structure

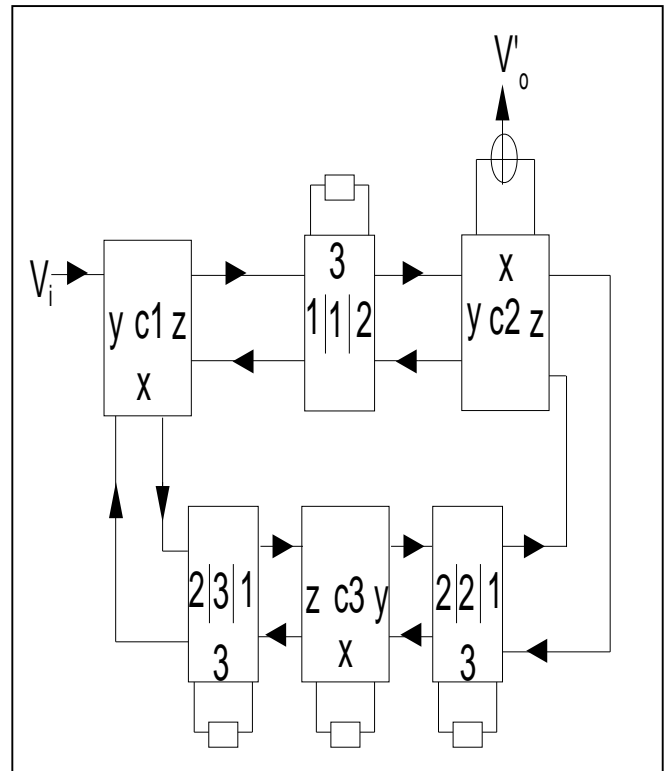


Fig.11. Port identification of Fig.10

And now replacing the parallel wire interconnection and analogue current conveyor with its digital equivalent as given in Fig. 5 and 6, the digital equivalent of general second order filter is derived as shown in Fig. 12. An output proportional to V_o can be formed by putting an adder at the output as shown in Fig. 11. The transfer function of the derived structure [14] can be obtained from the Eq. (2) and (8) given as

$$H_D(z) = [2H\{s\}]_{s \rightarrow \frac{z-1}{T(z+1)}} \quad (13)$$

By selection of different components for Y_3, Y_2, G_4 and Y_5 and then replacing these components with their digital equivalent [14] we can have digital equivalent of the corresponding filter.

IV. CONCLUSION

By using the concept of second generation positive current conveyor we derived the digital equivalent of first order and second order filters. So, it can be used as a new and easy mathematical tool for the synthesis of digital filters.

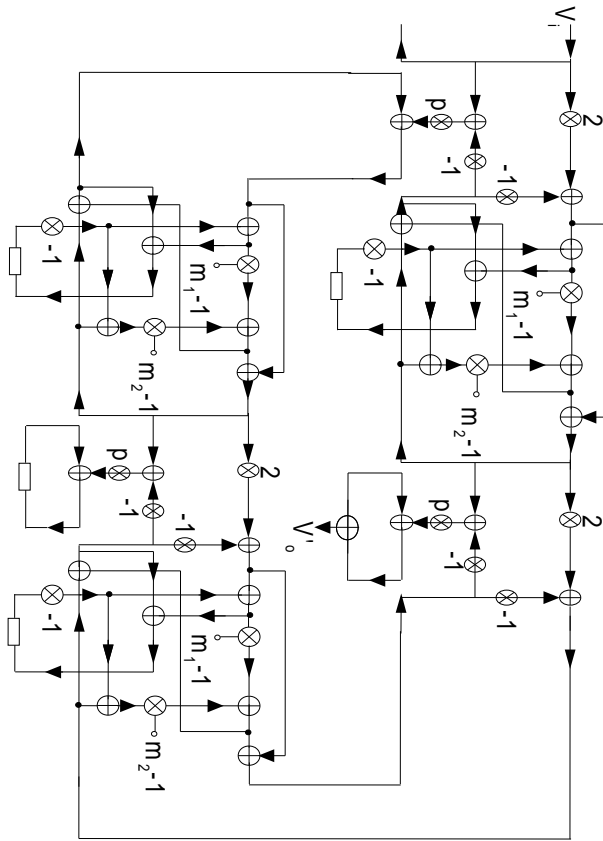


Fig.12. Digital equivalent of general second order filter structure

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Capitalize only the first word in a paper title, except for proper nouns and element symbols. For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

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