Design of Universal Multifunction Conveyor

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Abstract: - Today there are numerous active filter circuit solutions employing current or voltage conveyors. There are also a number of current and voltage conveyors of specific types. In the initial stages of the design they are considered in their idealized form, when their idealized models are used, which are made up of controlled current and voltage sources. To be able to assess whether the proposed structures are or are not suitable, it is necessary to have the possibility of realizing the designed circuits using real components, and also to have, already at the design stage, the most faithful models of real components so that the properties of the filter under consideration can be assessed as early as the design stage and the design of the envisaged filter made as effective as possible. The paper deals with the idea of so-called universal multifunction conveyor, which would enable realizing a certain group of both current and voltage conveyors, thus forming a multipurpose experimental element.

Key-Words: - conveyor, voltage conveyor, current conveyor, universal conveyor, conveyor structure

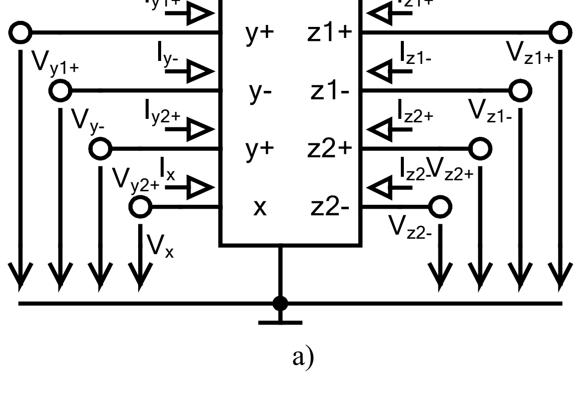
1 Introduction

Since most types of the current or the voltage conveyor are not commercially available, solutions have been sought that would yield a certain universal component, notwithstanding the fact that because of their universality these components do not exhibit as good properties as the specialized types do. However, their advantage is that connecting suitably one single component enables realizing a large scale of elements from the given types of conveyor. This is how the design of universal current conveyor and universal voltage conveyor came into being.

Current and voltage conveyors are active circuit elements that can generally operate in the voltage, current or mixed modes. In the course of time, three types (generations) of conveyor have been developed. During the theoretical investigation, elements were built that realized different types of conveyor depending on the interconnection of the terminals of the respective component part. Thus the universal current conveyor (UCC) and the universal voltage conveyor (UVC) have been designed. The basic description of the current conveyor properties is commonly known and can be found, for example, in [1], [2], [3], etc.

Current conveyors are becoming more and more common because of the current mode of their operation. Their advantages such as larger operation frequency range, good dynamic range, low-voltage operation, possibility of voltage, current and mixed mode operation, etc., have been presented in many publications. A number of current conveyor types have been designed, i.e. three-port and four-port conveyors, and the DVCC+/- five-port conveyor. Recently a new current conveyor has been developed and realized at our Faculty – the UCC. The UCC is an eight-port element that contains three high-impedance voltage inputs (y+, y-, y+), one low-impedance current input, and four high-impedance current outputs, see. Fig. 1. The UCC has been developed for its capability to simulate many types of a particular current conveyor, because it is known that only a few devices containing a separate current conveyor are on the market.

The schematic symbol and definition relations are given in Fig. 1.



a)

$$
\begin{pmatrix} I_{y1+} \\ I_{y-} \\ I_{y2+} \\ V_{x} \\ I_{z1+} \\ I_{z2+} \\ I_{z1-} \\ I_{z2-} \end{pmatrix} =
\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -1 & 0 & 0 & 0 & 0
\end{pmatrix}
\begin{pmatrix} V_{y1+} \\ V_{y-} \\ V_{y2+} \\ I_{x} \\ V_{z1+} \\ V_{z2+} \\ V_{z1-} \\ V_{z2-} \end{pmatrix}
$$

b)

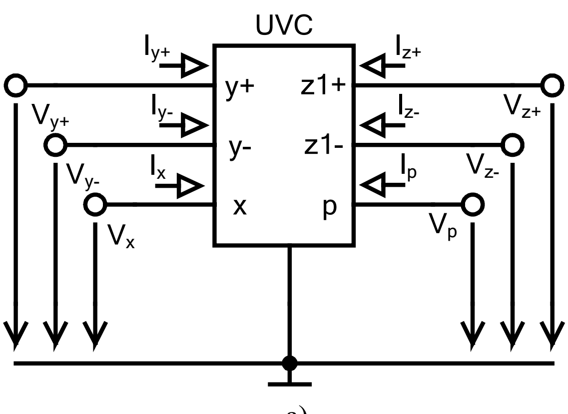
Fig. 1: Universal Current Conveyor: a) symbol, b) matrix formula describing its operation

For greater clarity, simple definition relations are given that follow from the above matrix:

$$V_x = V_{y1+} - V_{y-} + V_{y2+},$$
$$I_{y1+} = I_{y-} = I_{y2+} = 0,$$
$$I_{z1+} = I_{z2+} = I_x,$$
$$I_{z1-} = I_{z2-} = -I_x.$$

Another element is the voltage conveyor. It is an element dual to the current conveyor. The duality is understood here from the viewpoint of input and output impedances, which in the two elements are mutually dual. Up to now, voltage conveyors have not been produced as separate circuits.

Individual types of voltage conveyor are based on a certain similarity to current conveyors. This also holds for the universal voltage conveyor proposed above. The schematic symbol and definition relations of universal voltage conveyor are given in Fig. 2.



a)

$$
\begin{pmatrix} V_{y+} \\ V_{y-} \\ I_{x} \\ V_{z+} \\ V_{z-} \\ I_{p} \end{pmatrix} =
\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 1 \\
1 & -1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
\begin{pmatrix} I_{y+} \\ I_{y-} \\ V_{x} \\ I_{z+} \\ I_{z-} \\ V_{p} \end{pmatrix}
$$

b)

Fig. 2: Universal Voltage Conveyor: a) symbol, b) matrix formula describing its operation

For experimental purposes and practical confirmation of theoretical assumptions a universal current conveyor, UCCX, was designed, which was then produced in the AMI Semiconductor Company. The UCCX device was designed based on the CMOS 0.35 µm technology and called UCCX 0349 [4]. It contains one UCC. In addition to the UCC, the integrated circuit also includes a CCII+/- conveyor ($V_x = V_{y+}$, $I_{y+} = 0$, $I_{z+} = +I_x$, $I_{z-} = -I_x$), see Fig. 3. The basic connection includes external correction capacitors C_{C1} and C_{C2}, which are only used when the x-ports are loaded by capacities larger than 25 pF. Resistor R_{bia} (2.4 kΩ) is used to bias the UCC. Resistive trimmer R_T helps to compensate the voltage offset of UCC.

This element has been found capable of operating also in frequency bands of ca. tens of MHz.

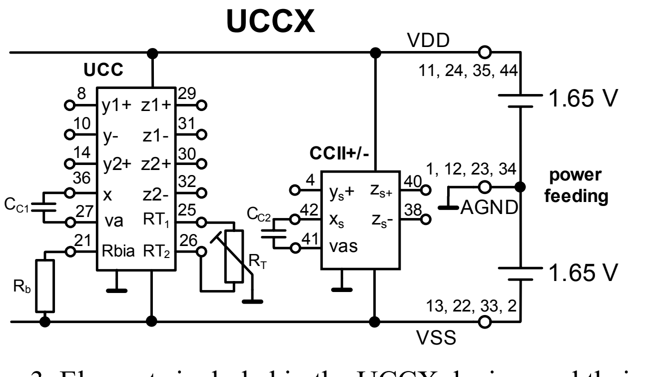
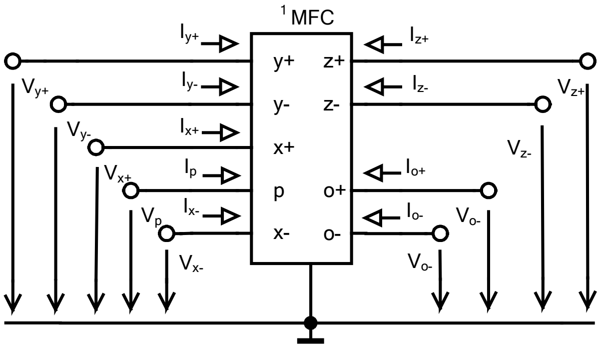


Fig. 3. Elements included in the UCCX device, and their pin connections (capacitors C_{C1}, C_{C2}, the resistor R_b, the trimmer R_T and power supplies are external components)

2 Definition of multifunction conveyor

As given above, in order to have a most faithful computer simulation and, above all, to enable practical experiments, it is necessary to create an element whose appropriate interconnection of terminals will provide for realizing different kinds of voltage and current conveyors. Starting from the element realized as given above, i.e. the universal current conveyor, and comparing the definition relations describing the voltage and the current conveyor, we can write the matrix formula and definition relations of the multifunction conveyor (MFC). Fig. 4 gives the symbol and the matrix formula of the proposed multifunction conveyor.



a)

$$\begin{pmatrix} V_{y+} \\ V_{y-} \\ I_{o+} \\ I_{o-} \\ I_{x+} \\ I_{x-} \\ V_{z+} \\ V_{z-} \\ I_{p} \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} . \begin{pmatrix} I_{y+} \\ I_{y-} \\ V_{o+} \\ V_{o-} \\ V_{x+} \\ V_{x-} \\ I_{o+} \\ I_{o-} \\ V_{p} \end{pmatrix}$$

b)

Fig. 4: Multifunctional conveyor: a) symbol, b) matrix formula describing its operation

3 Multifunction conveyor model

In the design of ideal multifunction conveyor model we start from the models of universal current conveyor and universal voltage conveyor. As mentioned above, the universal current conveyor has already been realized, and both the ideal model and the real model derived from the characteristics measured are available. The correctness of the basic structure of universal current conveyor is thus confirmed. For the universal voltage conveyor the internal structures have been designed while the simulations of partial circuits are still being carried out. Individual models can be found, for example, in [3], [5]. On the basis of this knowledge, an ideal model of multifunction conveyor has been created, which is shown in Fig. 5. Its internal structure includes current conveyors CCII+ and inverting current conveyors CCII-, and two voltage-controlled voltage sources (VCVS). This far, the model is similar to that of universal current conveyor. What has been added are two current-controlled current sources (CCCS). This structure fully realizes the relations described by the matrix in Fig. 4b. An advantage can be seen in that both the VCVS and the CCCS have always the same unity and positive gain**.** This model forms the initial structure for creating a frequency-dependent real model that is suitable for precise computer simulations.

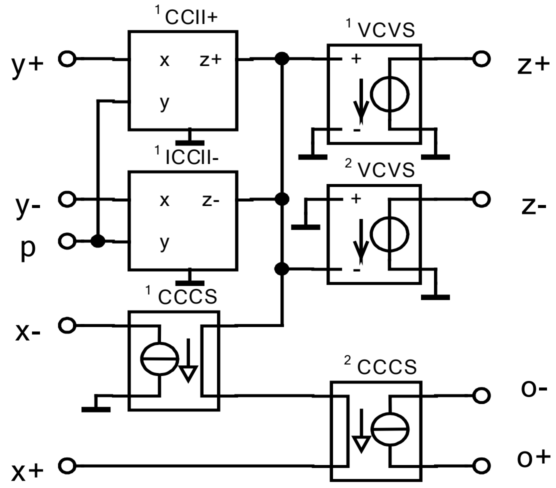


Fig. 5: Multifunction conveyor model

4 Connection of three-port current and voltage conveyors with MFC element

Examples will now be given of the basic connections of current and voltage conveyors with MFC element. Only simple current and voltage conveyors will be considered. Every connector is described by definition relations. For example, the CCII+/- is given uniquely by the relations $V_x = V_y$, $I_y = 0$, $I_z = +I_x$, $I_{z-} = -I$ (see above). The connection of a multifunction conveyor realizing the function of CCII+/- is shown in Fig. 6. Output current is taken from terminals o+ and o-, input x is conveyed to terminal y+, and input y is conveyed to terminal p. The non-used voltage terminals are non-connected while the non-used current terminals are earthed. It can be seen from the definition table of multifunction conveyor that this connection realizes the CCII+/- conveyor.

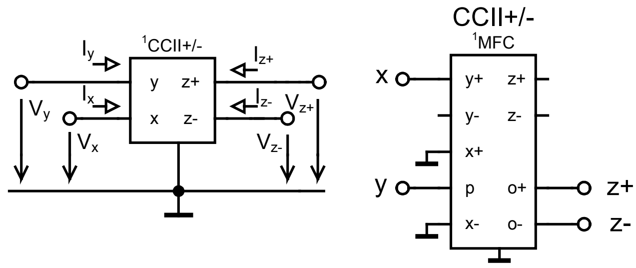


Fig. 6: CCII+/- conveyor with MFC

Similarly, we can obtain, for example, the VCII+/- voltage conveyor. Its connection with multifunction conveyor is given in Fig. 7 and the definition relations are $I_x = I_y$, $V_y = 0$, $V_{z+} = V_x$, $V_{z-} = -V_x$. In this case the output terminals are z+ and z- while the input terminals are y+ and x+. The non-used current terminals are earthed.

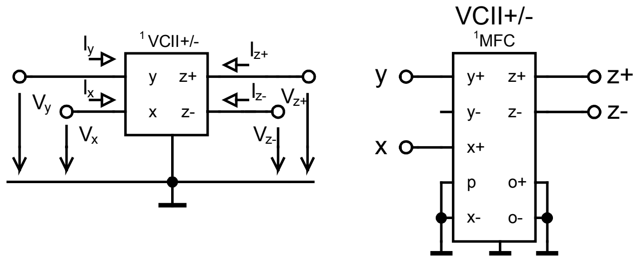
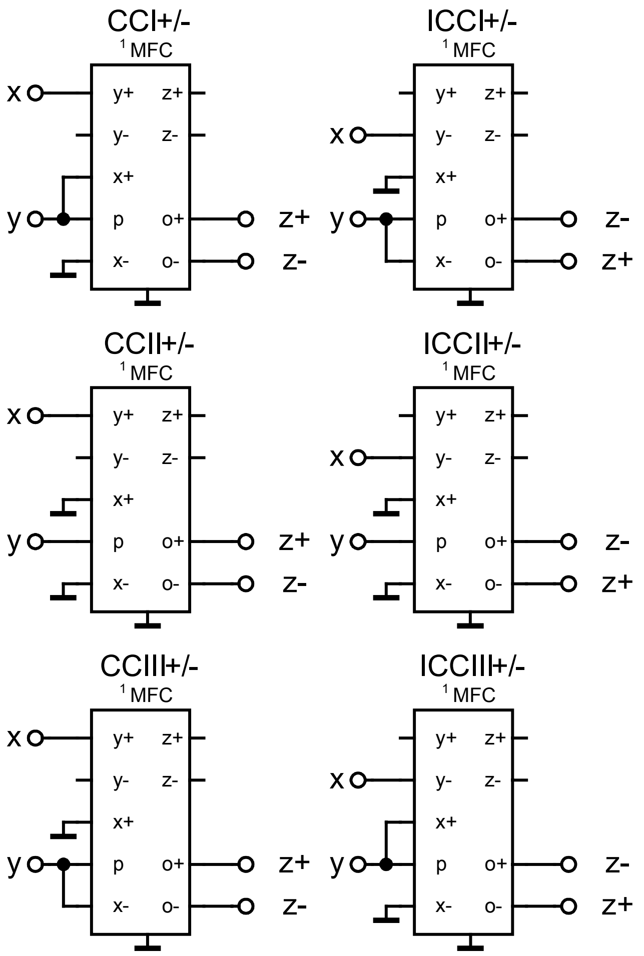
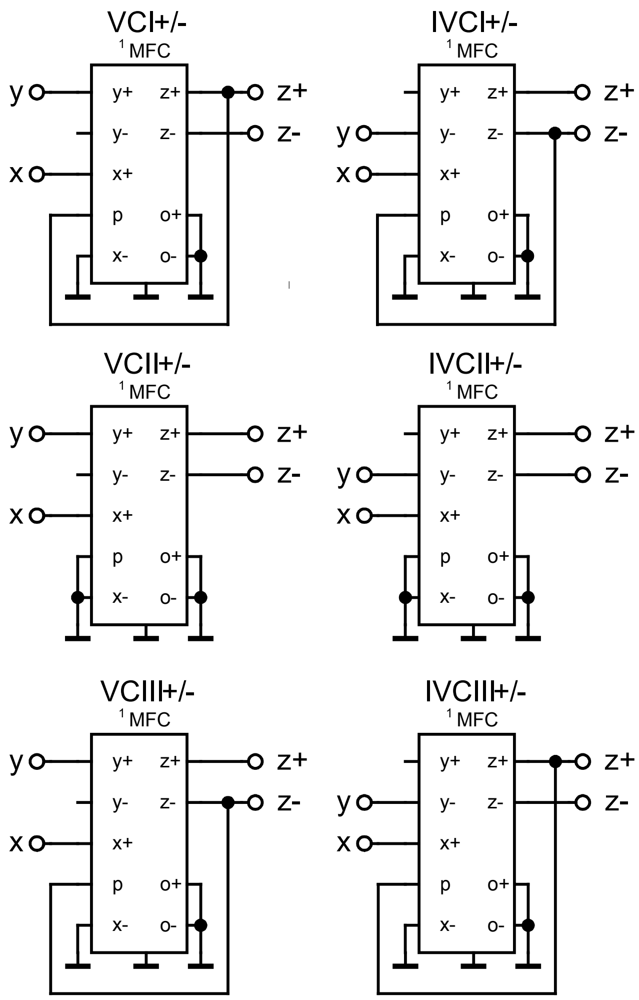


Fig. 7: VCII+/- conveyor with MFC

The connection of the different kinds and types of conveyor with MFC under consideration is shown in Fig. 8. As can be seen, using this element it is easy to realize different kinds and types of both current and voltage conveyors.



a)



b)

Fig. 8: Basic connection of conveyors with MFC: a) current conveyors, b) voltage conveyors

An example of the MFC element operating as a special voltage conveyor VCII+ is given in Fig. 9. It is a DC accurate second-order low-pass filter with the transfer function (1) .

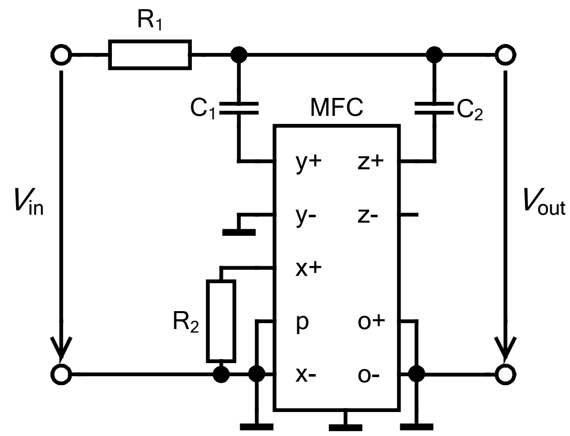


Fig. 9: DC accurate second-order low-pass filter with MFC element

$$K_{\mathrm{V}}(\boldsymbol{s}) = \frac{1}{\boldsymbol{s}^2 R_1 R_2 C_1 C_2 + \boldsymbol{s} R_1 (C_1 + C_2) + 1} \qquad (1)$$

5 Conclusion

The design and production of customized universal conveyors entail a number of technological problems, and the electrical properties are usually worse than is the case with dedicated circuits but the universal element offers application possibilities in a much wider area of diverse electronic circuits such as filters, integrators, converters, etc. To meet the demands of further development of and research into multiple connections with conveyors a universal element is obviously needed. This paper primarily puts forward the idea of a universal multifunction conveyor, whose benefits and possible realization are still to be analysed. As has been shown, it can be used as current as well as voltage conveyor of different kinds and types. Further development will focus on the analysis and design of the microelectronic structure. However, some changes to the basic functional properties of the proposed element cannot be excluded. To verify the properties of circuits with multifunction conveyors, either the proposed ideal model of multifunction conveyor can be used or a model with real properties estimated on the basis of results of measuring the properties of an already realized UCC can be created.

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