FLOATING RC NETWORKS USING CURRENT CONVEYORS

Kamil VRBA, Josef ČAJKA
and Václav ZEMAN
Technical University Brno
Institute of Communications
Antonínská 1, CZ-66201 Brno
Czech Republic

Abstract

The paper deals with the design of floating one- and/or two-port high-order networks. The current conveyor CCII+ seems to be a suitable active building block for this purpose. Some examples of the above mentioned networks are shown .

Keywords:

Current conveyors, floating networks, active filters

1. Introduction

When designing analog signal processing networks we sometimes need floating one-port or two-port networks. The suitability of current conveyors for this purpose has been shown already in [1]. Recently, the second-generation current conveyor CCII+ has appeared as a commercially available active building block CCII01 (LPT Electronics, Oxford, UK). The CCII01 device contains two CCII+ conveyors in one package. The internal structure of one CCII+ according to [2] is shown in Fig.1.

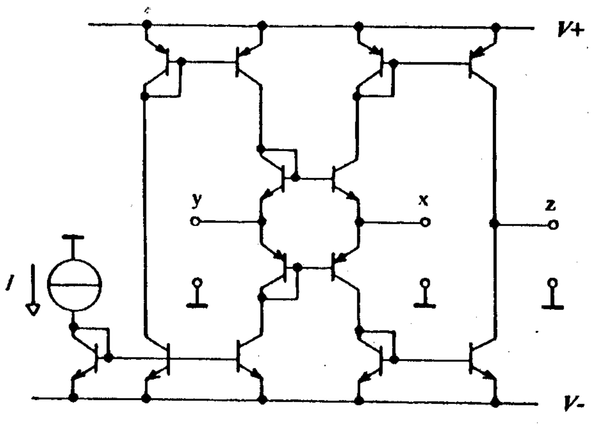


Fig. 1 Internal structure of a second-generation current conveyor CCII+

The currently used symbol for the current conveyor is shown in Fig. 2, where *x, y* and *z* are the usually used notations for conveyor terminals. For theoretical considerations we are using *ideal conveyors,* which are three-port immittance converters with one independent current I^* and two independent voltages. If we consider a second-generation ideal current conveyor CCII+ then it holds that $I_x = I^*$, $I_y = 0$, $I_z = I^*$ and $V_x = V_y$, whereas for the current coveyor CCII- we have $I_x = I^*$, $I_y = 0$, $I_z = -I^*$ and $V_x = V_y$.

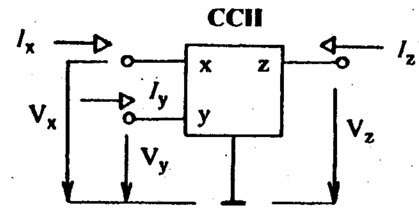


Fig. 2 The currently used scheme of a current conveyor

We have two possibilities for the floating network design: either to replace convetional operational amplifiers, voltage and current followers in already known schemes by equivalent current conveyors or to design completely new schemes with current conveyors.

2. Equivalent networks

Respecting the direction of nodal currents we can replace the three-terminal elements shown in Fig. 3, i.e. the ideal operational amplifier (Fig. 3a), the voltage follower (Fig. 3b) and the current follower (Fig. 3c), by an equivalent current conveyor CCII- . Its corresponding terminals (*x, y, z*) are shown in brackets in each scheme of the element to be replaced. If node *x* or *z* is common, we can use the CCII+ current conveyor instead of CCII- .

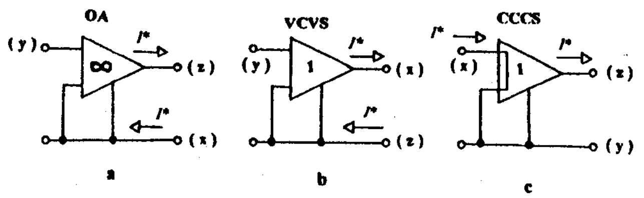


Fig. 3 Three-terminal network elements which can be replaced by an equivalent CCII- : a) ideal operational amplifier, b) voltage follower, c) current follower

Fig.4 shows four different realizations of CCII- conveyor with the aid of two CCII+ conveyors, i.e. using one CCII01 device. Here, too, the resulting terminals of the equivalent networks are denoted in brackets.

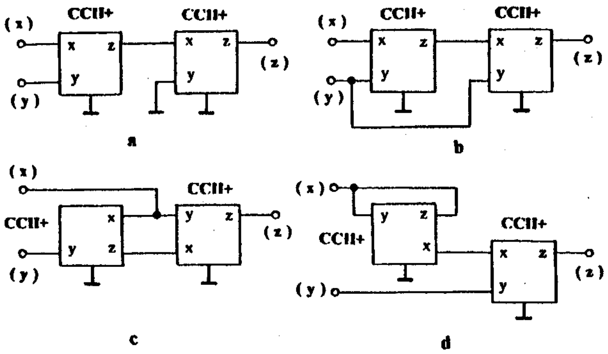


Fig. 4 Equivalent networks of a CCII- using two conveyors CCII+

The nullor (i.e. the pair nullator - norator) (Fig. 5a) or the ideal differential opamp (Fig. 5b) can be modelled with the aid of two CCI+ conveyors as shown in Fig. 5c.

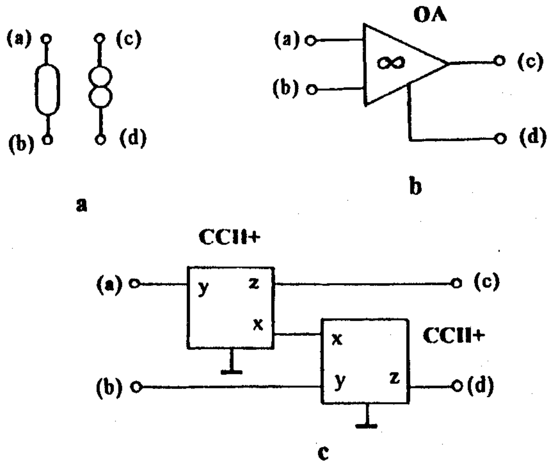


Fig. 5 Equivalent networks of a) the pair nullator-norator, b) the ideal differential opamp, c) two connected CCII+ conveyors

Two network elements are equivalent when they have identical matrices describing the element properties [7]. Writing the relations between the nodal currents and the independent current I^* and between the nodal and independent voltages we can state that this condition is satisfied for all the above mentioned equivalent networks.

3. Floating networks

Replacing both ideal differential opamps in the well-known *generalized immittance converter* (GIC) by two pairs of CCII+ according to Fig.5c we get a GIC with current conveyors as shown in Fig. 6. Here the two-port network is loaded by a one-port element Z_5. The input impedance of this two-terminal element has the standard form

$$Z_{in} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4}. \quad (1)$$

Eqn. (1) shows that we can realize one-ports with the following second-order immittance functions [3]

$$Y_D(s) = D_0 + D_1 s + D_2 s^2 \quad \text{or} \quad Z_X(s) = X_0 + X_1 s + X_2 s^2.$$

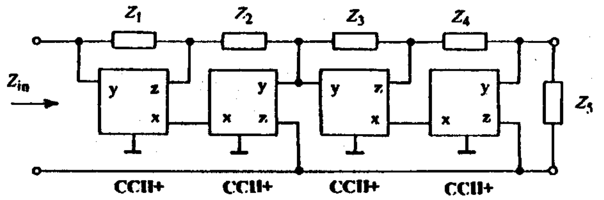


Fig. 6 Loaded generalized immittance converter (GIC)

We present now a new generalized low-pass filter with current conveyor in Fig. 7a. Let the LPF block be a two-port network charakterized by its cascade parameters ($V_1 = a_{11}V_2 - a_{12}I_2,\ I_1 = a_{21}V_2 - a_{22}I_2$). Its input port in the scheme is denoted by a bold dot, whereas the output port is denoted by a smal circle. The voltage transfer function of the whole two-port is as follows

$$\frac{V_{out}}{V_{in}} = \frac{1}{sC_x[a_{11}R_x + a_{12}] + 1}. \quad (2)$$

Eqn. (2) shows that the whole two-port network in Fig.7a works as a low-pass filter (a_{11} and a_{12} are in this case polynomials in s). The first-order LP filter of this type is drawn in Fig. 7b. This filter has the following voltage ratio: $V_{out}/V_{in} = 1/(sR_1C_1 + 1)$. Its cascade parameters are: $a_{11} = sR_1C_1 + 1$ and $a_{12} = 0$. We can easily let the order of the transfer function increase by replacing the LPF in Fig.7a by a high-order low-pass filter of the same type.

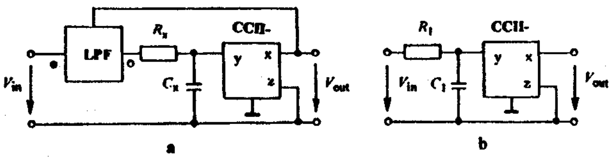


Fig. 7 a) General low-pass filter with one current conveyor CCII-, b) The basic scheme

As an example, Fig.8 shows a third-order low-pass filter of the above mentioned type. While the network represents a two-port (unloaded and without any feed-back), we could use the CCII+ conveyors instead of the CCII- ones. In this way we have designed a canonic structure. Its voltage ratio has the simplest form

$$\frac{V_{out}}{V_{in}} = \frac{1}{s^3 R_1 C_1 R_2 C_2 R_3 C_3 + s^2 R_2 C_2 R_3 C_3 + s R_3 C_3 + 1}. \quad (3)$$

Replacing resistors by capacitors and vice versa in Fig.8 we get a third-order high-pass filter.

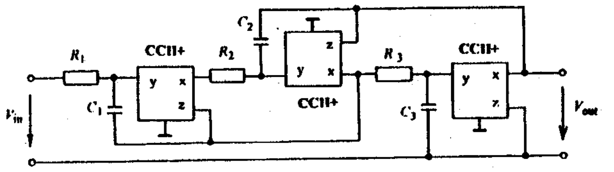


Fig. 8 Low sensitivity third-order low-pass filter

Another example is shown in Fig.9. Here the CCII+ current conveyor is connected as a negative immittance converter. The biquad presented in Fig. 9 has the following voltage transfer function (it is an inverting second-order band-pass filter)

$$V_{out}/V_{in} = -sR_2C_3/\{2s^2R_1C_1R_2C_2 + s[R_2(C_2 - C_3) + R_1C_2] + 1\} . \quad (4)$$

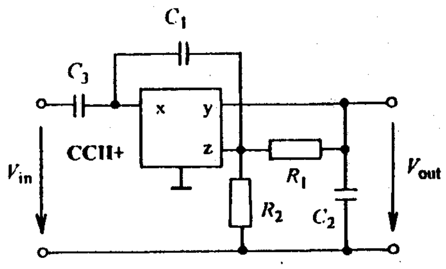


Fig. 9 Second-order band-pass filter with tunable Q-factor

This equation shows that we can control the Q-factor of the biquad by changing the capacitance value C_3 . Short-circuiting the input terminal-pair and fulfilling the oscillation condition $C_3 = C_2(1 - R_1/R_2)$ we get from this filter an oscillator oscillating at the angular frequency $\omega_0 = 1/(2R_1C_1R_2C_2)^{1/2}$ [4].

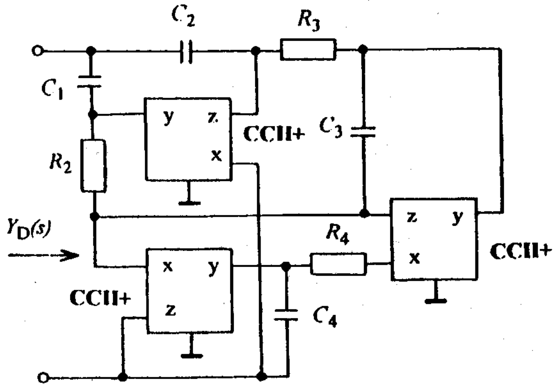


Fig. 10 Realization of a one-port element having the floating fourth-order admittance $Y_D(s)$ without the absolute term

The last example in Fig.10 shows a one-port element realizing the floating fourth-order admittance function without the absolute term

$$Y(s) = sD_1 + s^2D_2 + s^3D_3 + s^4D_4 \; .$$

The input admittance of this one-port element in Fig. 10 has the following form

$$Y_D(s) = s^4R_2R_3R_4C_1C_2C_3C_4 + s^3R_2R_4C_1C_2C_4 + s^2R_2C_1C_2 + s(C_1 + C_2) \; . \quad (5)$$

4. Filter simulation results

The properties of a real CCII+ from Fig.1 can be simulated with the aid of the model shown in Fig.11 [6]. For one conveyor in the CCII01 device we will consider the following parameter values in the model: $R_1 = 10\ \Omega$, $L_1 = 6$ nH, $C_1 = C_2 = 2$ pF, $R_2 = R_3 = 10$ MΩ, $C_3 = 1$ pF, $S = 0.1$ A/V.

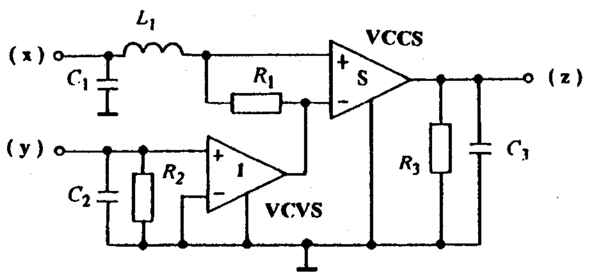
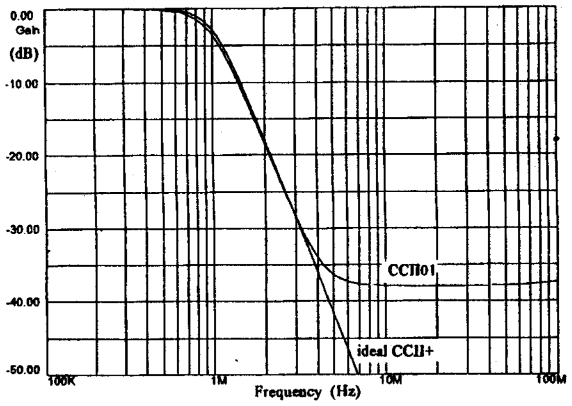


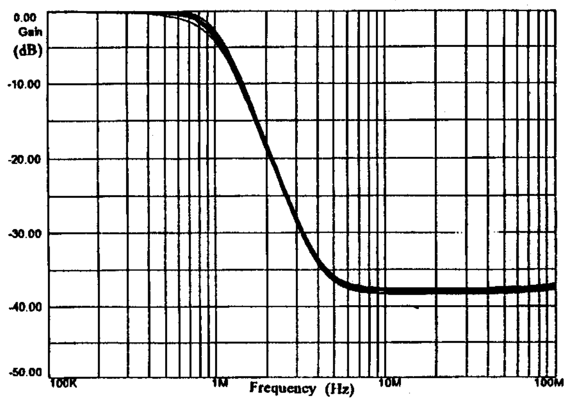
Fig. 11 Model of a device realizing the CCII+ curent conveyor shown in Fig.1

Let us return to the canonic third-order low-pass filter shown in Fig.8. We have computed the gain-frequency characteristic of this filter with the aid of the MC IV program. For simulation we have used the following parameter values: $C_1 = C_2 = C_3 = 100$ pF , $R = 796\ \Omega$, $R_2 = 1592\ \Omega$, $R_3 = 3183\ \Omega$. The cut-off frequency is $f_0 = 1$ MHz.

We got two curves (Fig. 12a), the first one is for the use of ideal CCII+ conveyors, the second one respects the CCII+ models according to Fig. 11. Using the MC IV program we have also tested the sensitivity of the frequency gain response to 5% parameter value variations. We used the Monte Carlo method. The results are drawn in Fig.12b. Evidently, the sensitivity of gain response to parameter variations is very low in this case.



a



b

Fig. 12 A set of simulated frequency responses for the third-order low-pass filter in Fig.8. a) gain-amplitude characteristic with ideal and with the simulated current conveyor, b) The Monte Carlo sensitivity of the gain response, if the assumed tolerance of all element parameters is 5%

5. Conclusions

We have described two ways for floating network realization using CCII+ current conveyors. The first method replaces conventional opamp by a CCII- current conveyor. We have shown how to substitute the above element by two CCII+ conveyors (i.e. by one CCII01 device). As a realization of new networks with CCII+ we have presented two examples. The results of a filter simulation are also indicated.

Application of CCII+ conveyors instead of the operational amplifiers enables us to expand the bandwidth of active filters up to several tens of MHz. Even new and unconventional circuit structures employing CCII+ can be designed.

The designed circuits with current conveyors were analysed with the aid of our COCO program [7].

Our research effort was supported by the Grant Agency of the Czech Republic.

6. References

[1] TOUMAZOU,C. - LIDGEY,F.J.: Floating-impedance convertors using current conveyors. Electronics Letters, 21, 1985, No.15, pp. 640-642.

[2] FABRE, A. - DAYOUB, F. - DURUISSEAU, L. - KAMOUN, M.: High Input Impedance Insensitive Second-Order Filters Implemented from Current Conveyors. IEEE Trans. Cicuits and Systems-I, Vol. 41, 1994, No. 12, pp. 918-921.

[3] VRBA, K. - ČAJKA, J.: Filters with Special Mutators. Elektrotechnický časopis (Journal of Electrical Engineering), 45, 1994, No.11, pp. 432-434.

[4] CELMA,S. - MARTINEZ,P.A. - CARLOSENA,A.: Approach to the synthesis of canonic RC-active oscillators using CCII. IEE Proc. - Circuits Devices Syst., Vol. 141, 1994, No. 6, pp. 493-497.

[5] VRBA, K. - ČAJKA, J.: New RC Networks Using Current Conveyors. Proc. Internat. AMSE Conference (SYS'95), Brno, Vol. 4, 1995, pp. 60-63.

[6] ZEMAN, V.: Analýza obvodů s transimpedančními operačními zesilovači (Analysis of networks containing transimpedance operational amplifiers). Proc. TELEKOMUNIKACE 95 Conference, Brno, UTKO FEI VUT, 1995, pp.128-130.

[7] ČAJKA, J. - FENCL, F.: New Version of the COCO Program. Radioengineering, Vol. 3, 1994, No. 3, pp. 18 - 21.

About authors,...

Josef ČAJKA was born in Vracov, Czech republic, in 1919. He received the M.E. degree in electrical engineering from VUT Brno in 1946, the Ph.D. degree from Military Academy Brno in 1961 and the DrSc. degree from the Technical University Brno in 1981. He was researcher with the Baťa Corp. in Zlín 1947-1951, then he joined the Military Acadamy Brno in 1951 and in 1972 the Technical University Brno. Since 1984, he has been Professor emeritus. His research and pedagogical interest was the Circuit Theory.

Kamil VRBA was born in Slavíkovice, Czech Republic, in 1949. He received the M.E. degree in electrical engineering in 1972 and the Ph.D. degree in 1977, both from Technical University in Brno. He joined the Institute of Telecommunications at the Faculty of Electrical Engineering and Computer Science of the TU in Brno. His research work is concentrated to problems aimed to accuracy of analog circuits.

Václav ZEMAN was born in Plzeň, Czech Republic, in 1965. He was graduated at the Technical University of Brno. In 1993 he entered the Department of Telecommunication at the Technical University of Brno as an assistant lecturer. Since 1993 he has started his doctoral studies in the specialisation "Electronics". The domain of his interest are Higher Order Synthetic Elements and computer modelling and simulation.