NEW RC-ACTIVE NETWORKS USING CURRENT CONVEYORS

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Abstract

Two novel autonomous networks containing current conveyors are presented. The design of second-order oscillators and frequency filters based on the above general networks is described. The Q-factor of the circuits designed is controllable through a grounded single resistor. Some examples illustrate the procedure described. Two new one-port elements for high-order immittance realization are shown.

Keywords:
Circuit theory, oscillators, filters, current conveyors

1. Introduction

Oscillators using second- and/or first-order generation current conveyors [1] have been published e.g. in [2], [3], [4] and [5]. All schemes described in above papers are based on a generalized autonomous network with a general characteristic equation containing one term with negative sign.

We will present two new autonomous networks of the same type and we shall show the RC network design based on our generalized circuit schemes.

2. Novel autonomous networks

One generalized network is based on an autonomous network drawn in Fig. 1. The circuit contains two second-generation current conveyors CCII+ replacing three-terminal nullators in a known *"nullors on a ring"* circuit [6]. The characteristic equation (CE) of this network has the following simple form

$$Y_1Y_2 - Y_3Y_4 = 0 \qquad (1)$$

The other generalized autonomous network is shown in Fig. 2. It contains two first- generation current conveyors CCI+ and four grounded one-port elements. Its general CE is

$$Y_1Y_4 + Y_2Y_3 - Y_3Y_4 = 0\,. \qquad (2)$$

Eqn. (2) corresponds to the general CE of networks published in [4] and [5], but our network is simpler than the published circuits. Besides that, we can interchange the terminals x and y of an arbitrary CCI+ in Fig. 2 without affecting CE (2). Inspecting (2) we see that we get again eqn. (2) if admittances Y_1, Y_2 and simultanously also admittances Y_3, Y_4 are interchanged.

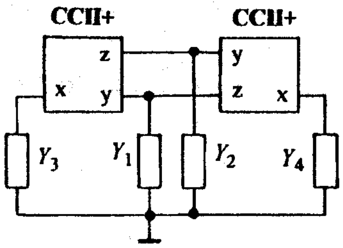


Fig. 1 Autonomous network containing current conveyors CCII+

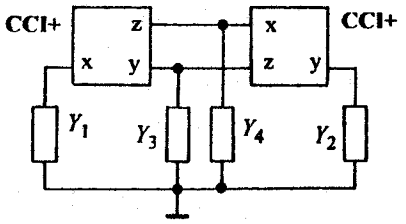


Fig. 2 Another autonomous network with current conveyors CCI+

3. Second-order oscillators and frequency filters

Let us return to the network in Fig. 1. If we choose $Y_1 = (G_1 + sC_1)$, $Y_2 = (G_2 + sC_2)$, $Y_3 = G_3$ and $Y_4 = G_4$, then we get the network shown in Fig. 3a. Inserting these admittances into (1) we obtain the following concrete characteristic equation of the circuit considered

$$s^2C_1C_2 + s(C_1G_2 + C_2G_1 - C_3G_3) + G_1G_2 = N(s) = 0. \qquad (3)$$

We got a CE of the general form:

$$a_2s^2 + a_1s + a_0 = 0\,. \qquad (4)$$

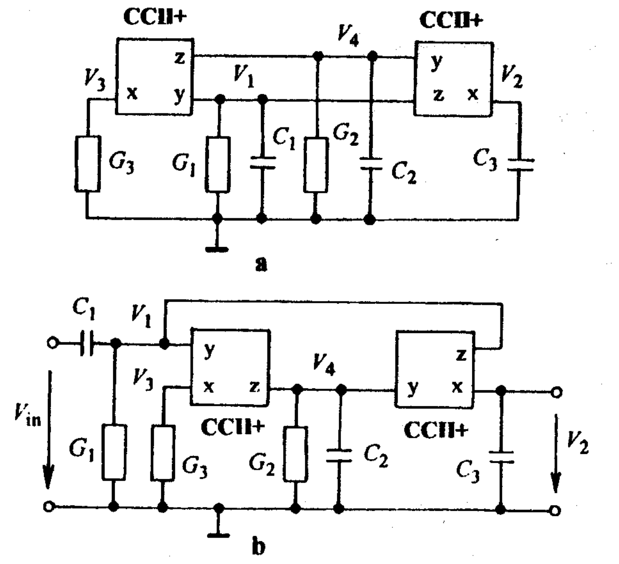


Fig. 3 a) Oscillator based on the circuit scheme in Fig. 1, b) two-port network derived from the autonomous network in Fig. 3a

From (4) we obtain quality factor Q = $[(a_0a_2)^{1/2}]/a_1$ and angular frequency $\omega_0 = (a_0/a_2)^{1/2}$. If the Q-factor tends to infinity, i.e. if the oscillation condition $C_1G_2 + C_2G_1 - C_3G_3 = 0$ is fulfilled, then the network in Fig. 3a oscillates on frequency ω_0.

The oscillation condition can be adjusted through conductivity G_3 of the grounded resistor without having any influence on the oscillation frequency.

From the autonomous network in Fig. 3a we can build a frequency filter so that we disconnect a one-port from the ground. The floating terminal of this one-port forms the live input node of a two-port . Then we try to find a suitable output port by examining successively all node voltages.

An example is shown in Fig. 3b. We have disconnected the capacitor with capacitance $C1$ and created the input port. If we take node voltage $V2$ as the output value then we get the following voltage transfer function

$$V_2/V_{in} = V_4/V_{in} = sC_1G_3/N(s) \tag{5}$$

Thus, we have realized a second-order band-pass filter (BPF).

All possible filters derived from Fig. 3a are shown in Table 1.

Considering the autonomous network in Fig. 2 we can choose: $Y_1 = G_1 + sC_1$, $Y_2 = G_2$, $Y_3 = G_3$ and $Y_4 = sC_2$. In this case we get an autonomous network drawn in Fig. 4a with the CE in the following form

$$s^2C_1C_2 + sC_2(G_1-G_3) + G_2G_3 = N_1(s) = 0. \tag{6}$$

From eqn. (6) we can see that the Q-factor of the network in Fig. 4a can be cotrolled only through grounded resistor G_1 and angular frequency ω_0 through another grounded resistor G_2. The oscillation condition $G_1 = G_3$ is in this case very simple.

Disconnecting the resistor with admittance G_1 from the ground and creating a two-port network as described above we obtain a filter shown in Fig. 4b. It can be used either as a low-pass or as a band-pass filter. The voltage transfer functions of filters which we can create from the network in Fig. 4a are presented in Table 2.

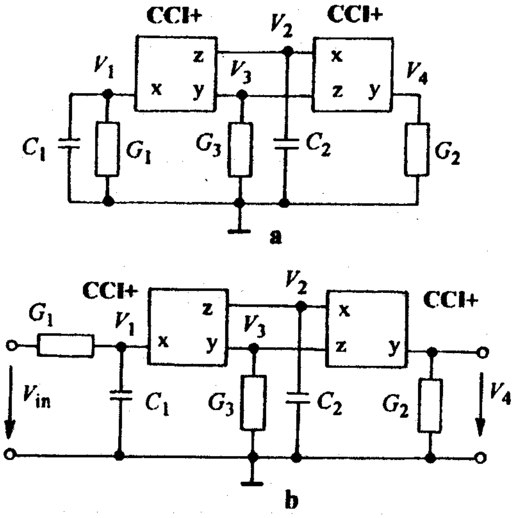


Fig. 4 a) Another oscillator based on the circuit scheme in Fig. 2, b) a two-port network derived from it

4. One-port networks

Modifying the circuit in Fig. 1 as shown in Fig. 5a we obtain a one-port network the input admittance of which is given as follows

$$Y_{in} = -s^2C_1C_2R_1 = \omega^2C_1C_2R_1 . \tag{7}$$

In this way , we can realize a grounded resistor with frequency-dependent conductance (FDPR D-type) .

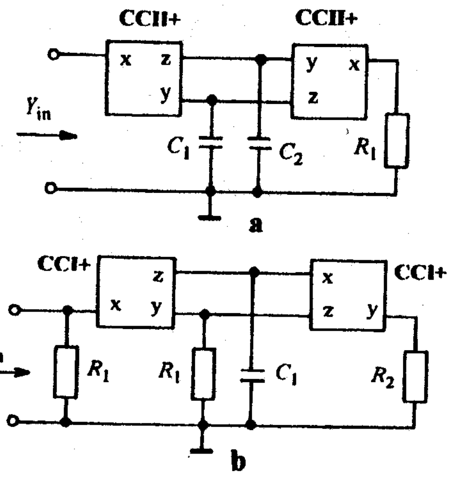


Fig. 5 Novel one-port elements: a) FDPR-D element, b) grounded synthetic inductor

Table 1 Voltage transfer functions of filters based on Fig. 3a

disconnected element	voltage ratio $V_1/V_{in} = V_3/V_{in} =$	filter type	voltage ratio $V_2/V_{in} = V_4/V_{in} =$	filter type
G_1			$G_1G_3/N(s)$	LPF
C_1			$sC_1G_3/N(s)$	BPF
G_2	$sC_3G_2/N(s)$	BPF		
G_3	$-sC_3G_3/N(s)$	BPF		
C_2	$s^2C_1C_2/N(s)$	HPF		

Table 2 Voltage transfer functions of filters created from network in Fig. 4a

disconnected element	voltage ratio $V_1/V_{in} = V_3/V_{in} =$	filter type	voltage ratio $V_2/V_{in} = V_4/V_{in} =$	filter type
G_1	$sC_2G_1/N_1(s)$	BPF	$G_1G_3/N_1(s)$	LPF
G_2	$sC_2G_2/N_1(s)$	BPF	$G_2G_3/N_1(s)$	LPF
C_1	$s^2C_1C_2/N_1(s)$	HPF	$sC_1G_3/N_1(s)$	BPF
C_2	$-sC_2G_1/N_1(s)$	BPF		

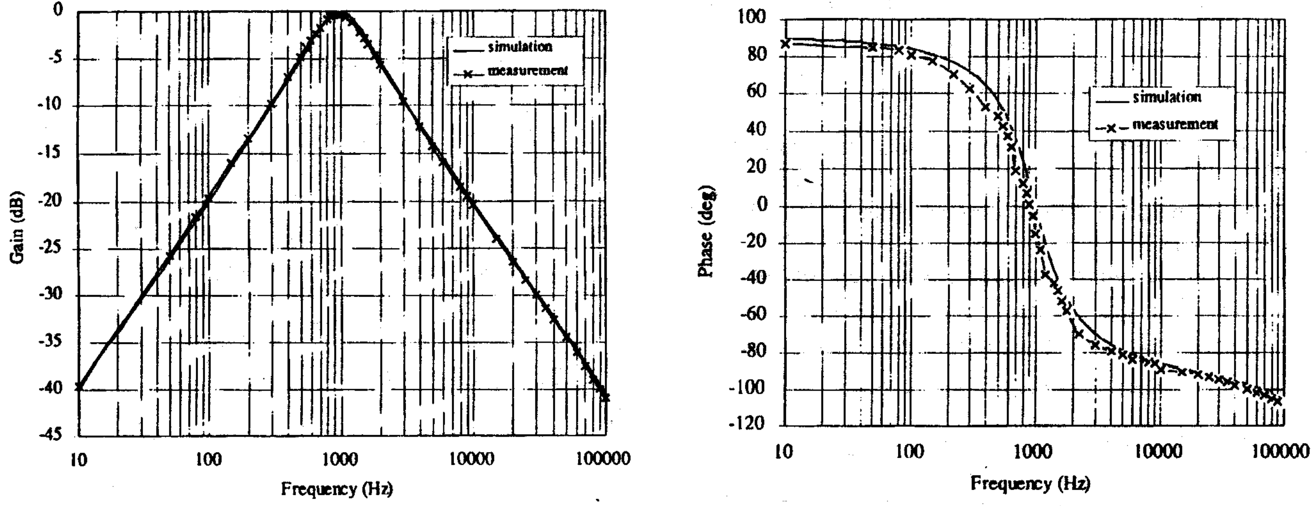
On the other hand, using the circuit in Fig. 2 we can realize a grounded synthetic inductor shown in Fig.5b. The input impedance of this one-port is given by following equation

$$Z_{in} = sC_1R_1R_2 \ . \qquad (8)$$

In both cases the quantity in question can be controlled through a grounded resistor.

5. Simulation and experimental results

We used the schematic in Fig. 3b and designed a BP filter with 3-dB bandwidth $\Delta f = 1$ kHz and a centre frequency $f_0 = 1$ kHz. The applied capacitances were $C_1 = C_2 = C_3 = 10$ nF, the resistances $R_1 = R_2 = R_3 = 16$ kΩ. The first part of AD844 opamp was used as CCII+. The plots of magnitude- and phase-frequency chracteristics of this BP filter obtained from the computer simulation and by measurement are shown in Fig. 6. We have used the PSpice 7.1 simulation program.



a b

Fig. 6 Simulated and measured magnitude- and phase-frequency responses of a band-pass biquad acc. to Fig. 3b.

6. Conclusions

All the one-port elements in the circuit schemes presented are grounded. If resistors are replaced here with capacitors and conversely, then we obtain a set of new circuits.

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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 Bat'a Corp. In Zlín 1947-1951, then he joined the Military Academy Brno 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 Brno. He joined the Institute of Telecomunications 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.

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