Frequenz
53 (1999)
3-4

New All-Pass and Notch Filters Using Current Conveyors

Neue Allpaß- und Kerbfilter unter Verwendung von Stromübertragern

Abstract
Two new high input impedance generalized configurations using the current conveyor and realizing an all-pass or a notch response are given. The two configurations are related to each other by interchanging the *X* and the *Z* ports of the current conveyor. PSpice simulations are included.

Übersicht
Es werden zwei neue allgemeine Schaltungsanordnungen mit hoher Eingangsimpedanz unter Verwendung von Stromübertragern vorgestellt sowie zwei Realisierungen als Allpaß- und Kerbfilter beschrieben. Die beiden Anordnungen gehen durch Vertauschen der *X*- und *Z*-Tore des Stromübertragers ineinander über. Die Schaltungen werden mit PSpice simuliert.

Für die Dokumentation
Stromübertrager / Kerbfilter / Allpaßfilter

By Ahmed M. Soliman*

1. Introduction

Several filter circuits are available for realizing the second order all-pass or notch transfer function using the op amp [1] or the current conveyor (CCII) as the active element [2-4]. Recently two high input impedance notch filter circuits using CCII- have been reported [5].

The purpose of this paper is introduce two new configurations with a high-input impedance for realizing the all-pass or the notch transfer function. The proposed configurations employ a CCII- and are related to each other by interchanging the *X* and the Z ports of the CCII-.

2. The Inverting Configuration Using CCII-

Fig.1 represents the new high-input impedance inverting configuration using the CCII-, where N represents the *RC* network shown in **Fig. 2**. It is well known that the network N shown in Fig. 2a can be used with this configuration to realize a notch response, by taking Z_1 as a series *RC* circuit and Z_2 as a parallel *RC* circuit [5].

Two additional realizations of unity gain notch filters may be obtained from the circuit of Fig. 1a using the generalized configuration of the *RC* network N shown in Fig. 2b. The transfer function in this case is given by

$$T_{oi}(s) \equiv \frac{V_o}{V_i} = -\frac{R_b}{R_a}\frac{Z_1(Z_2+Z_3+Z_4)+Z_2Z_3-\frac{R_a}{R_b}Z_2Z_4}{Z_1(Z_2+Z_3+Z_4)+Z_2Z_3+Z_2Z_4}. \quad (1)$$

There are two alternative all-pass and notch realizations that can be obtained using this configuration. The first realization is achieved with

$$Z_1 = R_1,\ Z_2 = \frac{1}{sC_2},\ Z_3 = \frac{1}{sC_1},\ \text{and}\ Z_4 = R_2; \quad (2)$$

for an all-pass response,

$$\frac{R_a}{R_b} = 1 + 2\frac{R_1}{R_2}\left(1+\frac{C_2}{C_1}\right) \quad (3)$$

on the other hand, for a notch response,

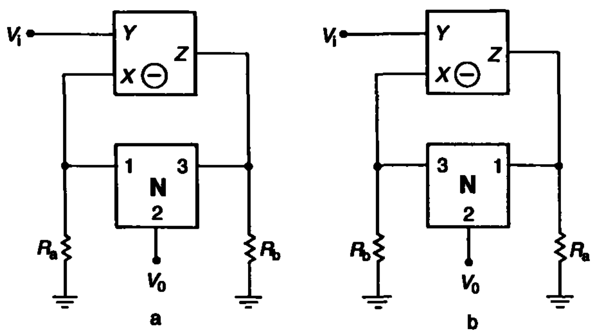

Fig.1: The high impedance CCII-, generalized configurations

$$\frac{R_a}{R_b} = \frac{R_1}{R_2}\left(1+\frac{C_2}{C_1}\right). \quad (4)$$

It is seen that a notch response with a gain factor = -1, can be obtained by taking

$$C_1 = C_2,\ R_2 = 2R_1\ \text{and}\ R_a = R_b. \quad (5)$$

Simulation is performed by using PSpice with the CCII-, realized by using two AD844A/AD biased with ±9 V, and taking $C_1 = C_2 = 1\text{nF}$, $R_1 = 1\ \text{k}\Omega$, $R_2 = 2\ \text{k}\Omega$ and $R_a = R_b = 2\ \text{k}\Omega$.

Fig. 3 represents the magnitude response of the notch filter, from which it is seen that the simulated notch frequency is given by 113.07 kHz, which is slightly higher than its theoretical value of 112.54 kHz.

The second possible realization using this configuration is obtained from the first realization by applying the *RC:CR* transformation [1], thus

$$Z_1 = \frac{1}{sC_1},\ Z_2 = R_2,\ Z_3 = R_1,\ \text{and}\ Z_4 = \frac{1}{sC_2}. \quad (6)$$

In this case the necessary conditions for an all-pass or a notch response are given respectively by

$$\frac{R_a}{R_b} = 1 + 2\frac{C_2}{C_1}\left(1+\frac{R_1}{R_2}\right) \quad (7)$$

$$\frac{R_a}{R_b} = \frac{C_2}{C_1}\left(1+\frac{R_1}{R_2}\right). \quad (8)$$

* Professor and Chairman, Electronics and Communications Engineering Department, Cairo University, Egypt

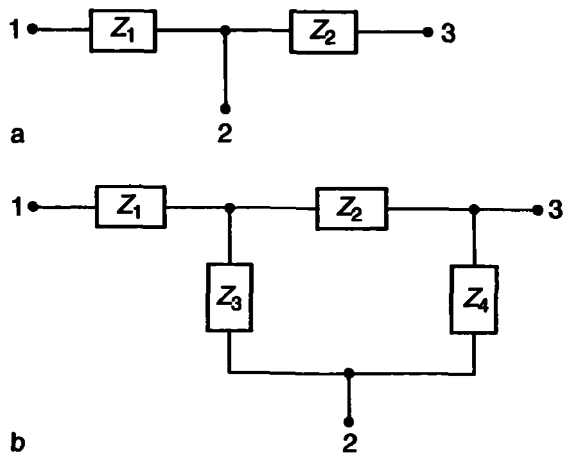

Fig.2a: The well known configuration of the *RC* network N
Fig.2b: The generalized configuration of the *RC* network N

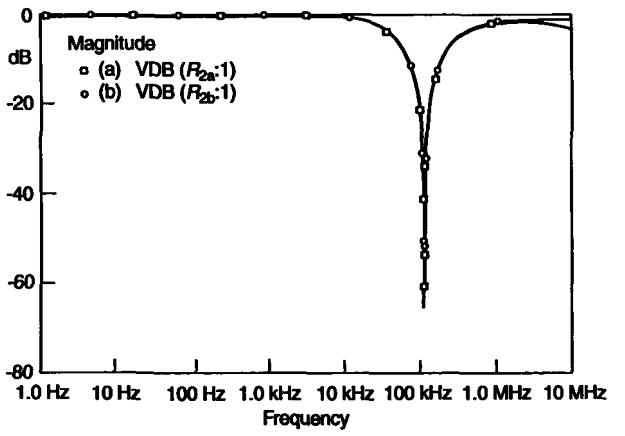

Fig.3: The magnitude response of the notch filters of Figs.1(a) and 1(b)

3. The Noninverting Configuration Using CCII−

A new noninverting configuration with a unity gain factor can be generated from the inverting configuration of Fig. 1a using the following lemma.

The *X* and *Z* ports interchange lemma:

Interchanging the *X* and the *Z* ports in the high input impedance CCII− circuit shown in Fig. 1a, where N represents a three port *RC* circuit with no ground terminal, results in the circuit shown in Fig. 1b whose transfer function T'_{oi} is given by

$$T'_{oi} = -\frac{R_a}{R_b} T_{oi} \tag{9}$$

where T_{oi} is the transfer function of the circuit shown in Fig. 1a.

Proof: By direct analysis, the transfer function of the circuit of Fig. 1a is given by

$$T_{oi} = -\frac{R_b}{R_a} + T_{21}\left(1+\frac{R_b}{R_a}\right) \tag{10}$$

where T_{21} is the transfer function of the passive *RC* network N which is defined as:

$$T_{21} = \frac{V_{23}}{V_{13}}. \tag{11}$$

Similarly, the transfer function of the circuit of Fig. 1b is obtained as

$$T'_{oi} = 1 - T_{21}\left(1+\frac{R_a}{R_b}\right) \tag{12}$$

Eqn. (9) is obtained from eqns. (10) and (12) which proves the lemma.

Applying the above lemma to the two circuits described in sec. 2 results in two more circuits that realize a unity gain factor all-pass or a notch response with the same design equations.

Fig. 3 shows the PSpice simulation results of the magnitude response of the noninverting notch filter which is generated from the inverting notch filter described in sec. 2 by interchanging the *X* and the *Z* ports of the CCII−. From the simulations, the notch frequency is found to be 112.02 kHz, which is slightly lower than its theoretical value of 112.54 kHz. It is worth noting that, the deviation in the notch frequency is due to the parasitic resistance R_x seen at port *X* and the stray capacitance C_z seen between port *Z* and ground.

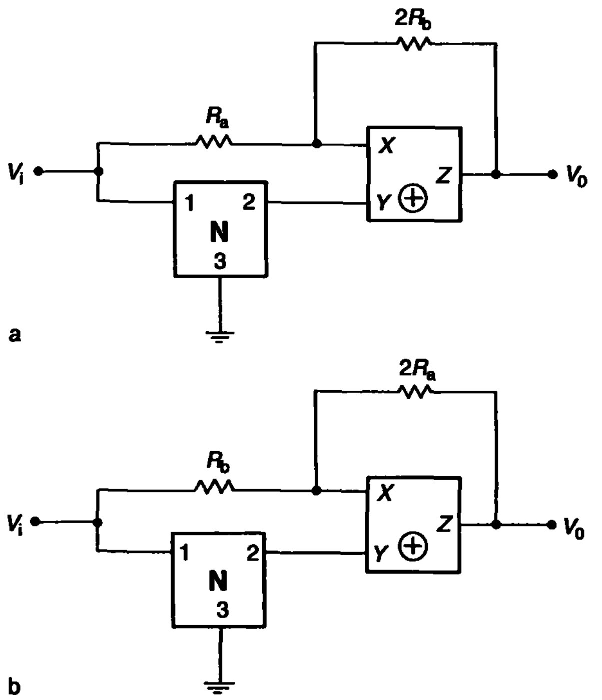

Fig.4: The CCII+, generalized configurations

It should be noted that the current mode circuits reported very recently [6] are related to the proposed voltage mode circuits by the adjoint network theorem [7].

4. Conclusions

Two new high input impedance generalized configurations using the CCII− and realizing an all-pass or a notch response are given. It is worth noting that the two well known configurations for realizing an all-pass or a notch response using the CCII+ shown in Fig. 4 [2–4] have the same transfer functions T_{oi} and T'_{oi} as those of the circuits of Fig. 1, and of course are related to each other by eqn. (9). The circuit transformation in this case however is achieved by the interchange of ports 1 and 3 of the network N as well as interchanging R_a and R_b, while keeping the feedback resistor multiplied by a factor of two in both cases. The network N shown in Fig. 2a has been used before with both configurations of Fig. 4 [2]. The network N of Fig. 2b can also be used with the generalized configurations of Fig. 4.

References

[1] Budak, A.: Passive and Active Network Analysis and Synthesis, Houghton Mifflin, 1974.

[2] Soliman, A. M.: Inductorless realization of an all-pass transfer function using the current conveyor, IEEE Trans. Circuit Theory, 20(1973) pp. 80–81.

[3] Soliman, A. M.: Another realization of an all-pass or a notch filter using a current conveyor, Int. J. of Electronics, 35 (1973) pp. 135–136.

[4] Soliman, A. M.: Synthesis of noniminimum phase RC transfer functions using the current conveyor, Proceedings sixth Hawaii international conference on system sciences (1973) pp. 506 -508.

[5] Liu, S.I., Tsao, H.W.: The single CC II biquads with high input impedance, IEEE Trans. Circuits Syst., 38 (1991) pp. 456–461.

[6] Soliman, A. M.: New current mode notch and all-pass circuits using the current conveyor, AEÜ, 50 (1996) pp. 224–226.

[7] Roberts, G. W.; Sedra, A. S.: A general class of current amplifier based biquadratic filter circuits, IEEE Trans. Circuits Syst. 39 (1992) pp. 257–263.

Prof. Dr. A. M. Soliman
Electronics and Communications Engineering Department
Cairo University, Egypt

(Received on August 18, 1998)