J. of Active and Passive Electronic Devices, Vol. 3, pp. 273–279
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Kerwin Huelsman Newcomb Filter Using Inverting CCII

AHMED M. SOLIMAN

Electronics and Communication Engineering Department, Cairo University, Egypt

A voltage mode Kerwin-Huelsman-Newcomb filter (KHN) using the Inverting CCII (ICCII) is given. The filter has high input impedance, employs two grounded capacitors, six grounded resistors and has independent control on Q and on the gain. A current mode KHN filter is generated from the voltage mode circuit. The current mode circuit has very low input impedance; employs grounded capacitors, grounded resistors and has independent control on Q and on the gain. Spice simulation result is included to demonstrate the practicality of the KHN circuit.

Keywords: Voltage mode; current mode; Inverting Current Conveyor; Filters.

1 INTRODUCTION

The inverting second generation current conveyor (ICCII) was introduced in [1] as a new block to be added to the current conveyor family. The ICCII is considered to be a special case from the Differential Voltage Current Conveyor DVCC introduced in [2,3] with a single Y input only. This active element can be easily implemented with CMOS technology as given in [1–3].

The symbolic representation of the ICCII is shown in Fig. 1. The relation between terminal voltages and currents is given by [1].

$$\begin{pmatrix} I_y \\ V_x \\ I_z \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{pmatrix} \begin{pmatrix} V_y \\ I_x \\ V_z \end{pmatrix} \tag{1}$$

The voltage at terminal X is the inversion of the voltage at terminal Y. The current at terminal Z follows the current at terminal X in magnitude. In Equation (1), the ± 1 specifies the type of the current conveyor (ICCII+ or ICCII−).

*Corresponding author. E-mail: asoliman@ieee.org

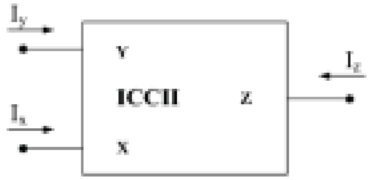

FIGURE 1
Inverting CCII symbol.

By convention, the positive sign is taken to mean that the currents at the X and Z terminals are both flowing inwards to the conveyor or outwards from the conveyor.

The important advantage of the ICCII$-$ is to obtain and design current-mode circuits from their voltage-mode counterparts using the adjoint network theorem [4,5] as explained in [1]. However a multi-output circuit will become a single output circuit after applying the theorem. The realization of the Tow Thomas (TT) filters using the DVCC and the ICCII is given in [2] and [6] respectively. The DVCC is also used in [3] to realize a current mode TT filter. It is desirable also to realize the Kerwin–Huelsman–Newcomb state variable filter (KHN) filter [7,8] using the ICCII building block. Both voltage mode and current mode filters using single output ICCII are given in this paper.

2 VOLTAGE MODE KHN

Figure 2 represents the voltage mode inverting highpass, noninverting band-pass and inverting lowpass KHN filter realized using four ICCII$+$ and one ICCII$-$.

The voltage transfer functions are given by:

$$\frac{V_{HP}}{V_i} = \frac{-\frac{s^2 R}{R_5}}{D(s)}, \quad \frac{V_{BP}}{V_i} = \frac{\frac{sR}{C_1 R_1 R_5}}{D(s)}, \quad \frac{V_{LP}}{V_i} = \frac{-\frac{R}{C_1 C_2 R_1 R_2 R_5}}{D(s)} \tag{2}$$

D(s) is given by:

$$D(s) = s^2 + \frac{R}{C_1 R_1 R_4} s + \frac{R}{C_1 C_2 R_1 R_2 R_3} \tag{3}$$

From (3) the ω_o and the Q of the filter are given by:

$$\omega_o = \sqrt{\frac{R}{C_1 C_2 R_1 R_2 R_3}}, \quad Q = R_4 \sqrt{\frac{C_1 R_1}{C_2 R R_2 R_3}} \tag{4}$$

It should be noted that R_4 controls Q without affecting ω_o of the filter.

Note also that the ω_o and the Q sensitivities to all circuit components are very low. It should be noted that the resistor R_5 controls the filter gain without affecting Q or ω_o of the filter.

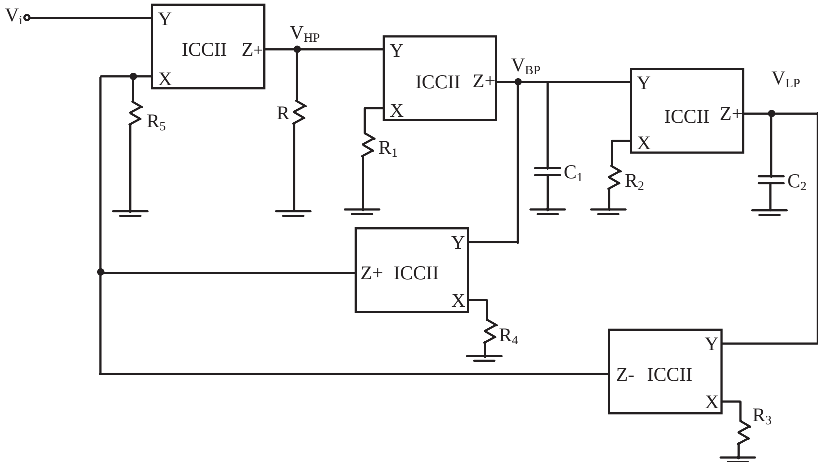

FIGURE 2
Voltage mode KHN filter using single output ICCIIs.

3 CURRENT MODE KHN

The current mode KHN filter is generated from the voltage mode circuit given in Fig. 2. The current mode KHN circuit has very low input impedance; employs grounded resistors and capacitors and has independent control on Q and on the gain. Figure 3 represents the KHN current mode filter which is generated from the voltage mode KHN filter shown in Fig. 2. The transformation method used to convert the voltage mode filter to a current mode filter has been used before in [9] to obtain current mode filters. The three output voltages are converted to the three output currents using three more ICCII.

Figure 3 is generated from Fig. 2 by injecting the input current to the X terminal of the first ICCII, grounding terminal Y and of course removing R_5. This circuit uses one ICCII$-$ and seven ICCII$+$ and is canonic as it uses only two capacitors.

The current transfer functions are given by:

$$\frac{I_{HP}}{I_i} = \frac{\frac{s^2 R}{R_6}}{D(s)}, \quad \frac{I_{BP}}{I_i} = \frac{-\frac{sR}{C_1 R_1 R_7}}{D(s)}, \quad \frac{I_{LP}}{I_i} = \frac{\frac{R}{C_1 C_2 R_1 R_2 R_8}}{D(s)} \tag{5}$$

D(s) is the same as given in (3).

The ω_o and the Q of the filter are the same as given in (4).

The non-inverting notch response is obtained by connecting I_{HP} and I_{LP} taking $R_6 = R$ and $R_8 = R_3$.

The non-inverting all-pass response is obtained by connecting I_{HP}, I_{BP} and I_{LP} taking $R_6 = R$, $R_8 = R_3$ and $R_7 = R_4$.

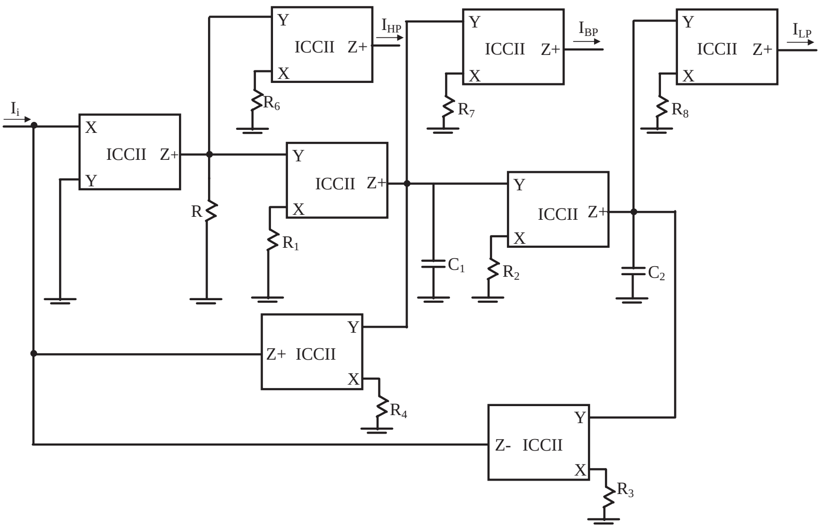

FIGURE 3
Current mode KHN filter using single output ICCIIs.

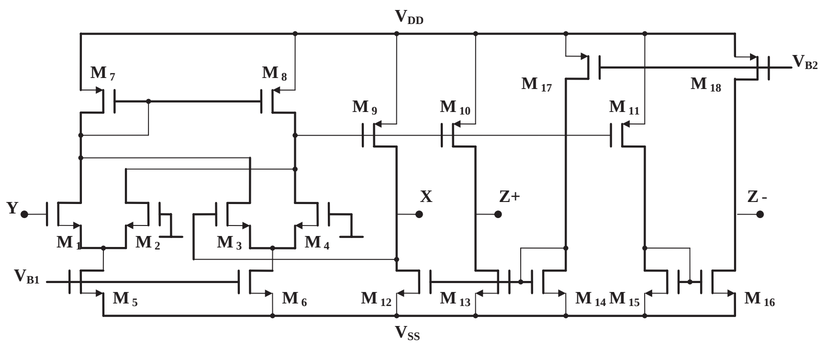

FIGURE 4
The CMOS circuit of the ICCII [3].

4 SPICE SIMULATIONS

Spice simulation results using technology SCN 05 feature size 0.5 μm from MOSIS vendor: AGILENT. Figure 4 represents the CMOS circuit of the ICCII with balanced outputs Z+ and Z− terminals that is used with the KHN circuit reported in this paper. The transistor aspect ratios are given in Table 1 and $V_{DD} = 1.5\,V$, $V_{SS} = -1.5\,V$, $V_{B1} = -0.52\,V$ and $V_{B2} = 0.33\,V$.

Figure 5(a) represents the magnitude and phase characteristics together with the ideal response of the bandpass output of the circuit of Fig. 2 designed to have $f_o = 2$ MHz, unity gain at the center frequency and $Q = 10$. The circuit

NMOS transistors	$W(\mu m) / L(\mu m)$
M_1, M_2, M_3, and M_4	25/0.5
M_5 and M_6	8/0.5
M_{12}, M_{13}, M_{14}, M_{15}, and M_{16}	20/2.5
PMOS transistors	$W(\mu m) / L(\mu m)$
M_7 and M_8	10/0.5
M_9, M_{10}, M_{11}, M_{17}, and M_{18}	40/2

TABLE 1
Aspect ratios of the MOS transistors of the ICCII of Fig. 4

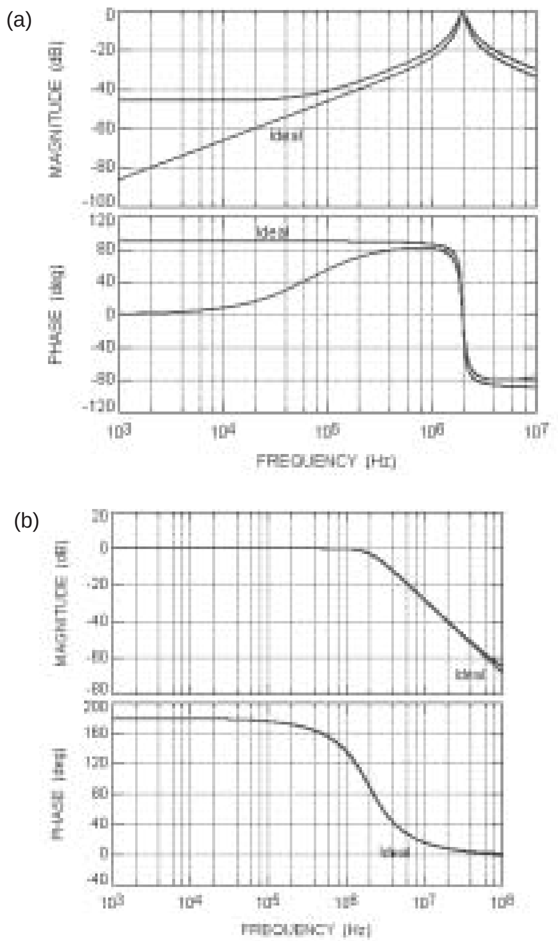

FIGURE 5
(Continued.)

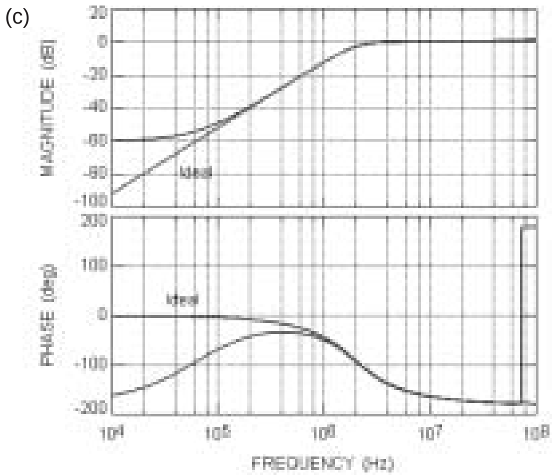

FIGURE 5
(a) The bandpass magnitude and phase characteristics and the ideal response. (b) The lowpass magnitude and phase characteristics and the ideal response. (c) The highpass magnitude and phase characteristics and the ideal response.

design parameters taken are $C_1 = C_2 = 10$ pF, $R_1 = R_2 = R_3 = R = 8\,\mathrm{k}\Omega$, $R_5 = R_4 = 80\,\mathrm{k}\Omega$.

It is seen that the simulated results agree well with the ideal responses.

Next, the circuit of Fig. 2 is simulated with $f_o = 2$ MHz, unity DC gain and $Q = 0.707$ for a maximally flat low-pass response. The circuit design parameters taken are $C_1 = C_2 = 10$ pF, $R_1 = R_2 = R_3 = R_5 = R = 8\,\mathrm{k}\Omega$, $R_4 = 5.656\,\mathrm{k}\Omega$. Figure 5(b) represents the magnitude and phase characteristics of the low-pass response together with the ideal characteristics. It is seen that the simulated results almost coincide with the ideal responses.

Figure 5(c) represents the magnitude and phase characteristics of the high-pass response together with the ideal characteristics. It is seen that the simulated results are close to the ideal responses.

5 CONCLUSIONS

A voltage mode KHN filter using the Inverting CCII (ICCII) is given. The filter has high input impedance, employs two grounded capacitors, six grounded resistors and has independent control on Q and on the filter gain. The current mode KHN filter is generated from the voltage mode circuit. The current mode circuit has; very low input impedance, employ grounded capacitors and has independent control on Q and on the gain. Spice simulations demonstrate the circuit practicality and are very close to the ideal responses.

REFERENCES

[1] Awad I. A. and Soliman A. M. The inverting second generation current conveyors: the missing building blocks, CMOS realizations and applications. *Int. J. of Electronics*, **84**, 1999, 413–432.

[2] Chiu W., Liu S. I., Tsao H. W. and Chen J. J. CMOS differential difference current conveyors and their applications. *IEE Proceedings-Circuits, Devices*, **143**, 1996, 91–96.

[3] Elwan H. O. and Soliman A. M. Novel CMOS differential voltage current conveyor and its applications. *IEE Proceedings-Circuits, Devices and Systems*, **144**, 1997, 195–200.

[4] Roberts G. W. and Sedra A. S. All current-mode selective circuits. *Electronics Letters*, **25**, 1989, 759–761.

[5] Carlosena A. and Moschytz G. Nullators and norators in voltage to current mode transformations. *Int. Journal of Circuit Theory and Applications*, **21**, 1993, 421–424.

[6] Soliman A. M. Voltage mode and current mode Tow Thomas bi-quadratic filters using ICCII. *Int. J of Circuit Theory and Applications*, **35**, 2007, 463–467.

[7] Kerwin W., Huelsman L. and Newcomb R. W. State variable synthesis for insensitive integrated circuit transfer functions. *IEEE J Solid State Circuits*, **2**, 1997, 87–92.

[8] Soliman A. M. Current conveyors steer universal filter. *IEEE Circuits and Devices Magazine*, **11**, 1995, 45–46.

[9] Soliman A. M. Current conveyor filters: Classification and review. *Microelectronics Journal*, **29**, 1998, 133–149.