INTERNATIONAL JOURNAL OF CIRCUIT THEORY AND APPLICATIONS
Int. J. Circ. Theor. Appl. 2007; **35**:463–467
Published online 22 January 2007 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/cta.398

LETTER TO THE EDITOR

Voltage mode and current mode Tow Thomas bi-quadratic filters using inverting CCII

Ahmed M. Soliman*, †

Electronics and Communication Engineering Department, Faculty of Engineering, Cairo University, Egypt

SUMMARY

A voltage mode Tow Thomas bi-quadratic filter using the inverting second-generation current conveyor (ICCII) is given. The filter has high input impedance, employs two grounded capacitors, and has independent control on Q, independent control on the band-pass and low-pass response gain. Three alternative current mode filters are generated from the voltage mode circuit. The three circuits have zero input impedance, employ grounded capacitors and have independent control on Q. Two of the circuits have also all resistors grounded and the other uses only ICCII− and has only one floating resistor. Copyright © 2007 John Wiley & Sons, Ltd.

Received 5 October 2006; Revised 7 December 2006

KEY WORDS: voltage mode; current mode; inverting second-generation current conveyor; filters

1. INTRODUCTION

The inverting second-generation current conveyor (ICCII) was first 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 difference current conveyor (DDCC) introduced in [2, 3] with a single Y input only. This active element can be easily implemented with complementary metal oxide semiconductor (CMOS) technology as given in [1–3].

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

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

*Correspondence to: Ahmed M. Soliman, Electronics and Communication Engineering Department, Faculty of Engineering, Cairo University, Egypt.
†E-mail: asoliman@idsc.net.eg

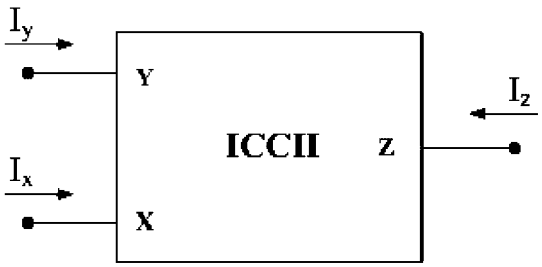

Figure 1. The block diagram of the ICCII.

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−). By convention, the positive sign is taken to mean that the current at the X and Z terminals are both flowing inwards to 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 well-known Tow Thomas (TT) filter using the DDCC is given in [2]. The DDCC was also used in [6] to realize a universal filter. It is desirable here to realize the TT filter [7] using the ICII building block. This will be added to the family of current conveyor-based TT filters [8].

2. THE VOLTAGE MODE TOW THOMAS CIRCUIT

Figure 2(a) represents the voltage mode non-inverting band-pass and low-pass TT filter using two ICCII− and one ICCII+.

The voltage transfer functions are given by

$$\frac{V_{\mathrm{BP}}}{V_i} = \frac{s/C_1R_3}{D(s)}, \quad \frac{V_{\mathrm{LP}}}{V_i} = \frac{1/C_1C_2R_1R_3}{D(s)} \tag{2}$$

$D(s)$ is given by

$$D(s) = s^2 + \frac{s}{C_1R} + \frac{1}{C_1C_2R_1R_2} \tag{3}$$

From Equation (3) the ω_{o} and the Q of the filter are given by

$$\omega_{\mathrm{o}} = \sqrt{\frac{1}{C_1C_2R_1R_2}}, \quad Q = R\sqrt{\frac{C_1}{C_2R_1R_2}} \tag{4}$$

It should be noted that R controls Q without affecting ω_{o} of the filter. R_3 controls the filter gain without affecting ω_{o} or Q.

Note also that the ω_{o} and the Q sensitivities to all circuit components are very low.

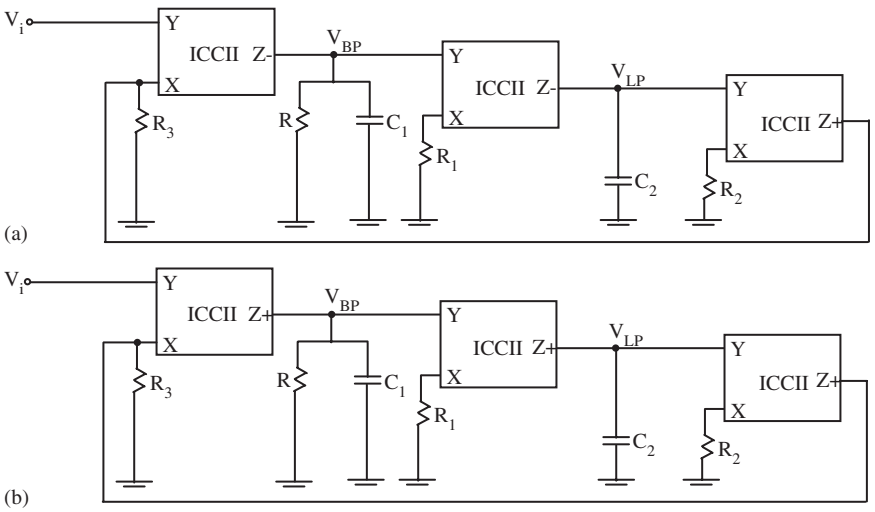

Figure 2. (a) The voltage mode Two Thomas biquad filter using single output ICCIIs and (b) the voltage mode Two Thomas biquad filter using only single output ICCII(+).

Figure 2(b) represents the TT filter using all ICCII+ whose CMOS realization is given as special case from the DDCC in [3]. It has the same equations as the circuit of Figure 2(a), except that the band-pass response will be inverting as in the original op amp TT circuit.

3. THE CURRENT MODE TOW THOMAS CIRCUIT

A current mode band-pass and low-pass filter using the DDCC was reported in [2]. It has, however, a non-zero input impedance and is frequency-dependent, employ three capacitors and the independent control on Q is achieved by varying a capacitor rather than a resistor as desirable. Besides it needs additional current followers to deliver the output currents rendering the circuit to have two floating resistors. It should be noted that the current mode filter using three ICCII+ and given in [9] has the disadvantages of using floating capacitors and has no independent control on Q.

Three alternative current mode filters are generated from the voltage mode circuits given in Figure 2. The proposed circuits have zero input impedance; employ grounded capacitors and having independent control on Q. Two of the circuits have all resistors grounded and the other uses only ICCII− and has one floating resistor.

Figure 3(a) is generated from Figure 2(a) by injecting the input current to the X terminal of the first ICCII−, grounding terminal Y and removing R_3. The current transfer functions are given by

$$\frac{I_{\mathrm{BP}}}{I_i} = \frac{s/C_1R_3}{D(s)}, \quad \frac{I_{\mathrm{LP}}}{I_i} = \frac{1/C_1C_2R_1R_4}{D(s)} \tag{5}$$

$D(s)$ is the same as given by Equation (3) and ω_{o} and the Q of the filter are the same as given by Equation (4). This circuit uses four ICCII− and one ICCII+ and is canonic as it uses only two capacitors and has all resistors and capacitors being grounded.

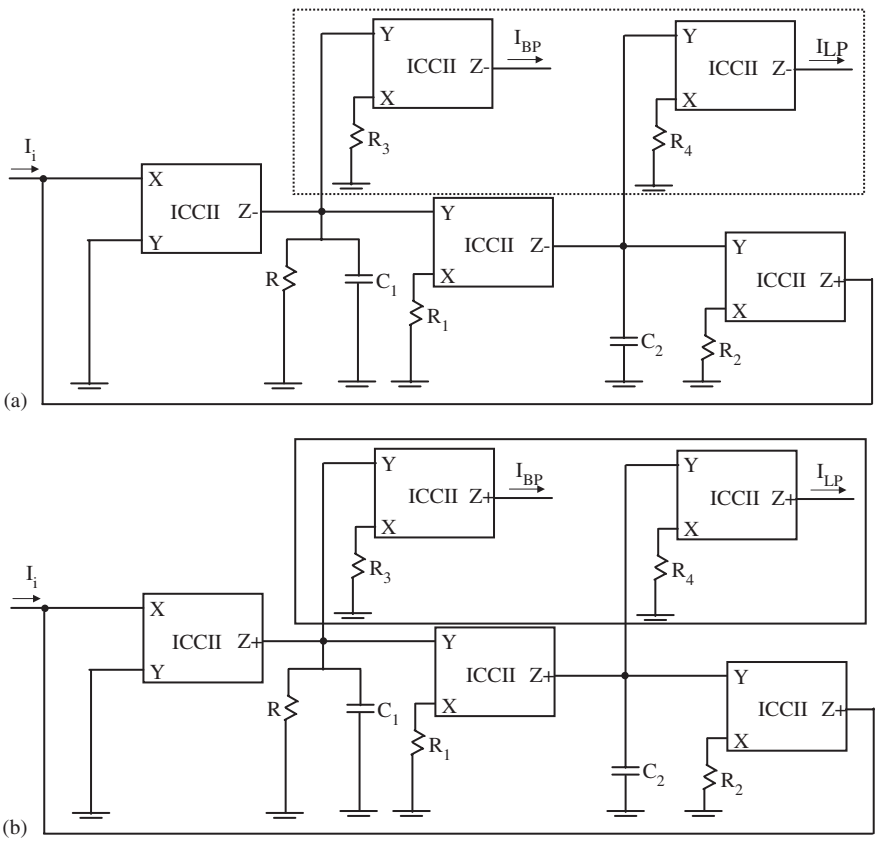

Figure 3. (a) The current mode Two Thomas biquad using single outputs ICCIIs and (b) the current mode Two Thomas biquad using only single outputs ICCII(+).

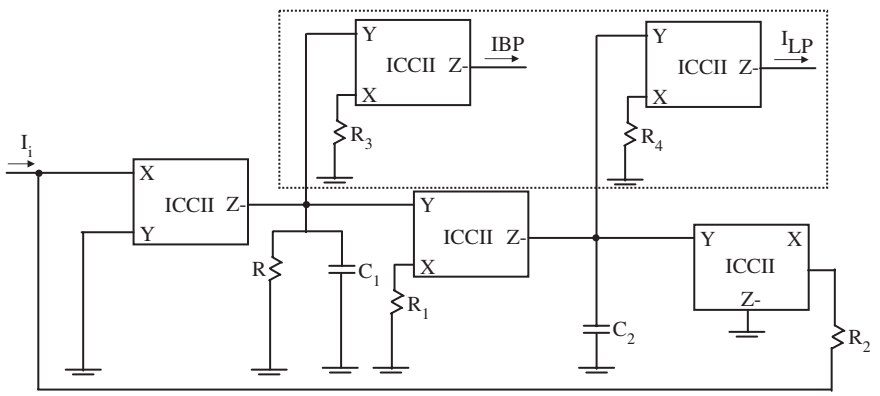

Figure 4. The current mode Two Thomas biquad using only single output ICCII(−).

Figure 3(b) is the current mode version of Figure 2(b) and it uses only ICCII+. The current transfer functions are the same as given by Equation (5), except I_{LP} will be inverting.

To complete the TT ICCII family of circuits using the ICCII, it is desirable to have an all ICCII− filters. Figure 4 represents the current mode TT using five ICCII−. Note that the resistor R_2 that delivers the feedback current to the X terminal of the first ICCII− is floating.

4. CONCLUSIONS

A voltage mode TT bi-quadratic filter using the ICCII is given.

The filter has high input impedance, employs two grounded capacitors, has independent control on Q, has independent control on the band-pass and the low-pass response gains by varying grounded resistors. Three alternative current mode filters are generated from the voltage mode circuit. All circuits reported have zero input impedance, employ grounded capacitors and have independent control on Q. Two of the circuits have all resistors grounded and one of them uses only ICCII+, the other uses only ICCII− and has one floating resistor.

It is worth noting that due to the importance of the ICCII the interest should be directed towards new CMOS realizations of this new member of the CCII family [10, 11].

REFERENCES

1. Awad IA, Soliman AM. Inverting second-generation current conveyors: the missing building blocks, CMOS realizations and applications. *International Journal of Electronics* 1999; **86**:413–432.
2. Chiu W, Liu SI, Tsao HW, Chen JJ. CMOS differential difference current conveyors and their applications. *IEE Proceedings*, *Circuits*, *Devices and Systems* 1996; **143**:91–96.
3. Elwan HO, Soliman AM. A novel CMOS differential voltage current conveyor and its applications. *IEE Proceedings*, *Circuits*, *Devices and Systems* 1997; **144**:195–200.
4. Roberts GW, Sedra AS. All current-mode selective circuits. *Electron Letters* 1989; **25**:759–761.
5. Carlosena A, Moschytz GS. Nullators and norators in voltage to current mode transformations. *International Journal of Circuit Theory and Applications* 1993; **21**:421–424.
6. Chang CM, Al-Hashimi BM, Wang CL, Hung CW. Single fully differential current conveyor biquad filters. *IEE Proceedings*, *Circuits*, *Devices and Systems* 2003; **150**:394–398.
7. Ghausi MS, Laker KR. *Modern Filter Design*, *Active RC and Switched Capacitor*. Prentice-Hall: Englewood Cliffs, NJ, 1981.
8. Soliman AM. New inverting–non-inverting band-pass and low-pass biquad circuit using current conveyors. *International Journal of Electronics* 1996; **81**:577–583.
9. Ozguz S, Toker A, Cicekoglu Q. First order all-pass sections based current mode universal filter using ICCIIs. *Electron Letters* 2000; **36**:1443–1444.
10. Lopez-Martin AJ, Ramirez-Angulo J, Carvajal RG. A proposal for high performance CCII-based analogue CMOS design. *International Journal of Circuit Theory and Applications* 2005; **33**:379–391.
11. Cajka J, Dostal T, Vrba K. General view on current conveyors. *International Journal of Circuit Theory and Applications* 2004; **32**:133–138.

