

# NEW FIRST-ORDER ALLPASS FILTERS EMPLOYING SINGLE MODIFIED THIRD GENERATION CURRENT CONVEYOR

Seckin Bodur<sup>1</sup>

Hakan Kuntman<sup>2</sup>

Oguzhan Cicekoglu<sup>3</sup>

<sup>1</sup>The Scientific and Technical Research Council of Turkey, Marmara Research Center, Information Technologies Research Institute, 41470, Gebze, Kocaeli, TURKEY

<sup>2</sup>Istanbul Technical University, Faculty of Electrical and Electronics Engineering, Department of Electronics and Communication Eng., 80626, Maslak, Istanbul, TURKEY

<sup>3</sup>Bogazici University, Faculty of Engineering, Department of Electrical and Electronics Eng., 80815 Bebek-Istanbul, TURKEY

<sup>1</sup>E-mail: seckinb@btae.mam.gov.tr <sup>2</sup>E-mail: kuntman@ehb.itu.edu.tr <sup>3</sup>E-mail: cicekogl@boun.edu.tr

## ABSTRACT

*The third generation current conveyor (CCIII) presented by Fabre is shown to be a useful active element to pick up the current of a floating passive element. CCIII can be considered as a current controlled current source with unity gain. The use of controlled sources with unity gain in the design of active-RC filters leads to structures with tight design equations. In order to relieve these, it may be useful to insert a gain larger than unity. The modified third generation current conveyor (MCCIII) is a newly introduced active building block to realize this property and to provide new possibilities in the circuit synthesis. In this paper, four new first-order allpass filter configurations employing a single modified third-generation current conveyor (MCCIII) are presented. To demonstrate the advantages of the proposed circuit topologies, a quadrature oscillator is designed employing the proposed allpass sections. SPICE simulation results verifying theoretical analyses are also included.*

### Keywords:

## 1. INTRODUCTION

Opamp-based circuits exhibit several drawbacks in their performance arising from the limited bandwidth and slew-rate of these active elements. As a result, current-mode approach has been increasingly recognized as a way to

overcome the op-amp drawbacks and to realize high speed systems. In the last decade, various new current-mode active building blocks have received considerable attention due to their larger dynamic range and wider bandwidth including second generation current conveyors (CCII) and

Received Date : 14.02.2003

Accepted Date: 15.06.2004

current-feedback op-amps (CFOA) [1-3]. The third generation current conveyor (CCIII) presented by Fabre [4] is shown to be a useful active element to pick up the current of a floating passive element. However it is shown that Fabre's conveyor can also be used to implement different circuit blocks [5, 6]. A CMOS implementation of CCIII is presented in [7]. CCIII can be considered as a current controlled current source with unity gain. The use of controlled sources with unity gain in the design of active-RC filters leads to structures with tight design equations. In order to relieve these, it may be useful to insert a gain larger than unity. In a recent work, a new active building block, modified CCIII (MCCIII) is introduced to realize this property and to provide new possibilities in the circuit synthesis using this element [8].

On the other hand, allpass filters are widely used in analog signal processing in order to shift the phase while keeping the amplitude constant, to produce various type of filter characteristics and to implement high-Q frequency selective circuits [9-11].

In this paper, we propose four new first-order allpass filter realisation using the MCCIII. The additional port of the MCCIII provides further design possibilities. From this point of view, the circuit is advantageous compared to the first-order allpass filter topologies realized with the conventional CCIII [4]. In order to show the usefulness of the proposed allpass section, a quadrature oscillator is designed. Simulation results verifying theoretical analysis are also included.

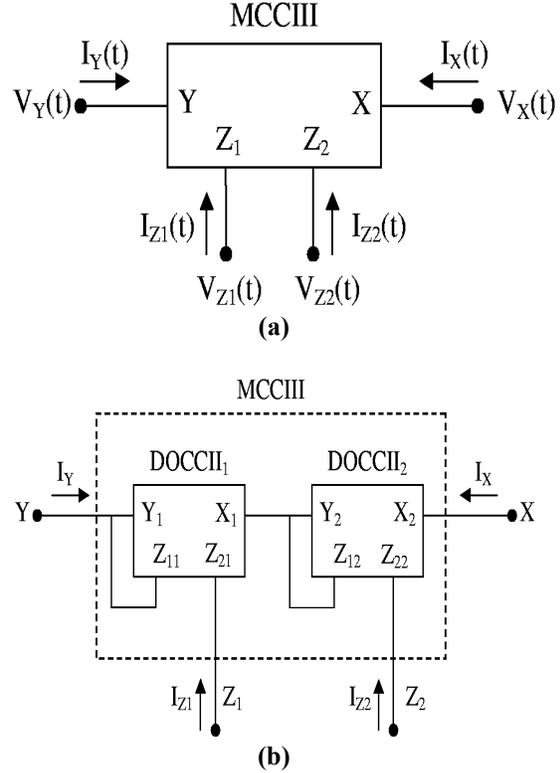
## 2. THE MODIFIED THIRD GENERATION CURRENT CONVEYOR

An ideal modified third generation current conveyor shown in Fig. 1a is characterized by the following constitutive relations [4]:

$$\begin{pmatrix} I_Y \\ V_X \\ I_{Z1} \\ I_{Z2} \end{pmatrix} = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & -k & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix} \begin{pmatrix} V_Y \\ I_X \\ V_{Z1} \\ V_{Z2} \end{pmatrix} \tag{1}$$

According to this equation, the element offers a current gain of -1 between ports X and Y, a

current gain of 1 between ports X and Z2 and a current gain of -k (usually k=2) between ports X and Z1. The latter property enables new possibilities in circuit design. This property is achieved simply by designing DOCCII<sub>1</sub> to provide a current gain of k at the port Z<sub>21</sub>.



**Figure 1. a)** Ideal modified third generation current conveyor, **b)** realization of the modified third generation current conveyor with two DOCCII<sub>s</sub>.

## 3. THE MCCIII IMPLEMENTATION AND THE PROPOSED FIRST-ORDER ALLPASS FILTER

Fig.2 illustrates proposed current-mode allpass filters using a single MCCIII. The related transfer functions are also given in Fig. 2 [11-14]. Note that the multiplier k provides flexibility to obtain any desired gain value for the allpass transfer function which is not possible for the standard CCIII.

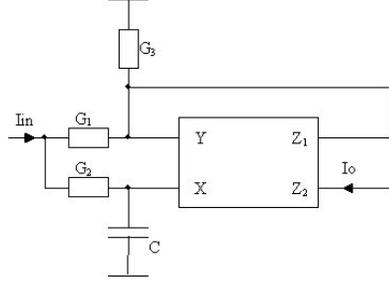
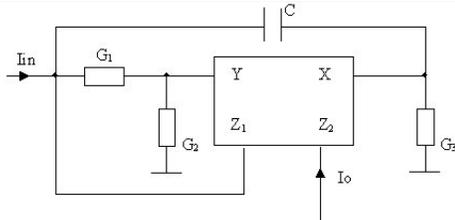
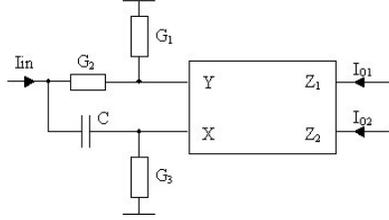
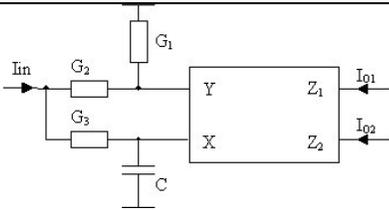
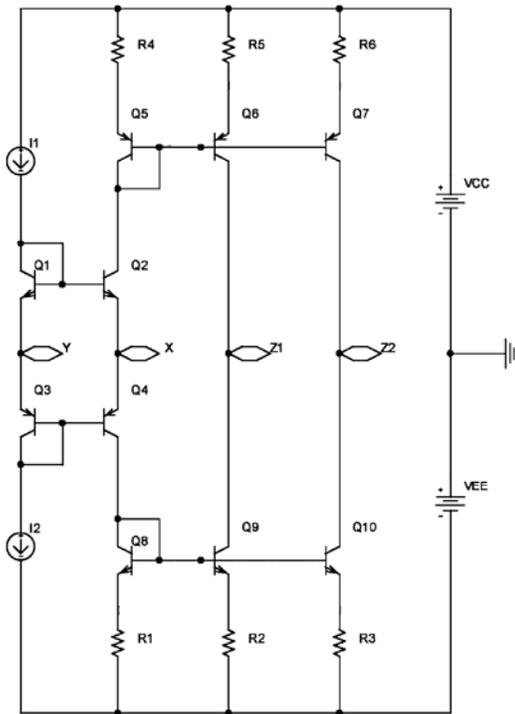
Allpass Filter Topology	Transfer Function
 <p style="text-align: center;">(a)</p>	$\frac{I_o}{I_{in}} = \frac{1}{(2+k)} \frac{G_3 - sC(1+k)}{G_3 + sC(1+k)}$ <p>for <math>G_1 = G_2(1+k)</math></p>
 <p style="text-align: center;">(b)</p>	$\frac{I_o}{I_{in}} = \frac{-2G_3G_2}{(G_3 + G_2)^2} \frac{(G_1G_3 - sCG_2)}{(G_1G_3 + sCG_2)}$ <p>for <math>k = \frac{G_3^2 - G_2^2}{2G_3G_2}</math></p>
 <p style="text-align: center;">(c)</p>	$\frac{I_{o1}}{I_{in}} = \frac{k G_2 - sC}{2 G_2 + sC} \quad \frac{I_{o2}}{I_{in}} = -\frac{1}{2} \frac{G_2 - sC}{G_2 + sC}$ <p>for <math>G_1 = G_3</math></p>
 <p style="text-align: center;">(d)</p>	$\frac{I_{o1}}{I_{in}} = -\frac{k G_1 - sC}{2 G_1 + sC} \quad \frac{I_{o2}}{I_{in}} = \frac{1}{2} \frac{G_1 - sC}{G_1 + sC}$ <p>for <math>G_2 = G_3</math></p>

Figure 2. Proposed Allpass filter topologies employing single MCCIII

#### 4. SIMULATION RESULTS

In this section, the simulation results of the proposed circuits are given. In the simulations, MCCIII<sub>s</sub> are implemented with DOCCII<sub>s</sub> illustrated in Fig.3 as shown in Fig.1. Note that the emitter resistor ratios  $R_1/R_3$  and  $R_4/R_6$  in DOCCII<sub>1</sub> are two times of the corresponding ratios in DOCCII<sub>2</sub> to provide the necessary current gain  $k=2$  of the MCCIII.

The supply voltages are taken as  $\pm 5V$ . The transistors used in the simulations are PRN-100 and PRP-100 npn and pnp transistors. Simulation results of the first-order allpass filter topology shown in Fig.2d are illustrated in Fig.4.



**Figure 3.** DOCCII used to implement MCCIII

The passive components are taken as  $R_1=R_2=R_3=1k\Omega$ ,  $C=1nF$ . From the simulation results, it is seen that the magnitude and phase characteristics agree well. Note that the output  $Z_2$  corresponds to conventional CCIII where the allpass functions are available with an attenuation of  $-6dB$ . This loss is compensated by the MCCIII at port  $Z_1$  which can be considered an advantage of these new active elements

To demonstrate the advantages of the proposed circuit topologies, a quadrature oscillator is designed employing the proposed allpass sections.

The quadrature oscillator is constructed by using the allpass sections of Figure 2c and 2d in a loop as shown in Fig.5. The first circuit provides a phase shift of

$$\varphi_{AP3}(\omega) = -2 \cdot \arctg(\omega \tau_1), \quad \tau_1 = C_1 R_2 \quad (2)$$

The second allpass circuit yields

$$\varphi_{AP4}(\omega) = 180 - 2 \cdot \arctg(\omega \tau_2), \quad \tau_2 = C_2 R_4 \quad (3)$$

The oscillation frequency of the circuit is obtained as

$$\omega = \frac{1}{\sqrt{\tau_1 \tau_2}} \quad (4)$$

The waveform at the output  $I_{O1}$  of the quadrature oscillator is given in Fig.5b. From Eq.4 we obtain an oscillation frequency of  $f_0 = 225079Hz$ . SPICE simulations yield an oscillation frequency of  $f_0 = 219768Hz$  which demonstrates clearly that the simulation result is in good agreement with the theory. Furthermore, it can be easily observed from Fig. 5b that the circuit exhibits a good large signal behaviour. The output signal is of the order of  $1mA$  for the bipolar realization circuit of Fig.3.

#### 5. CONCLUSIONS

In this study, four first-order allpass filter realisations based on modified third generation current conveyors are presented. A quadrature oscillator realized with MCCIII<sub>s</sub> based on the proposed allpass sections are also included. Spice simulations are carried out to verify theory. Proposed topologies provide additional design possibilities for current-mode allpass filter realizations employing conventional current conveyors given in the literature.

#### 6. ACKNOWLEDGEMENT

This work is partially supported by Bogazici University Research Fund with the project code 02A201.

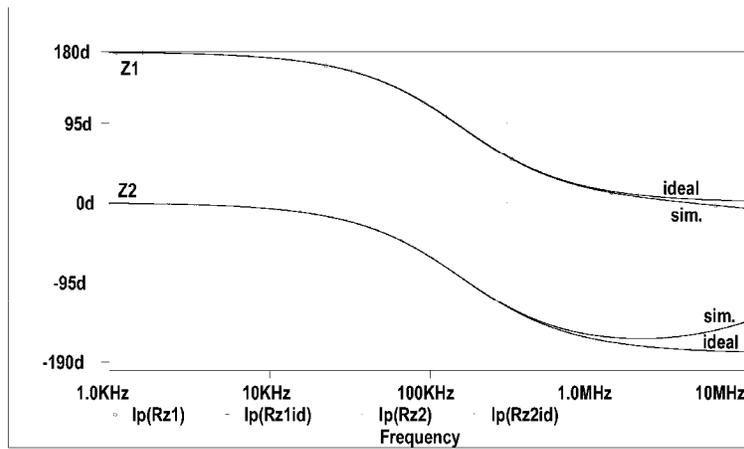
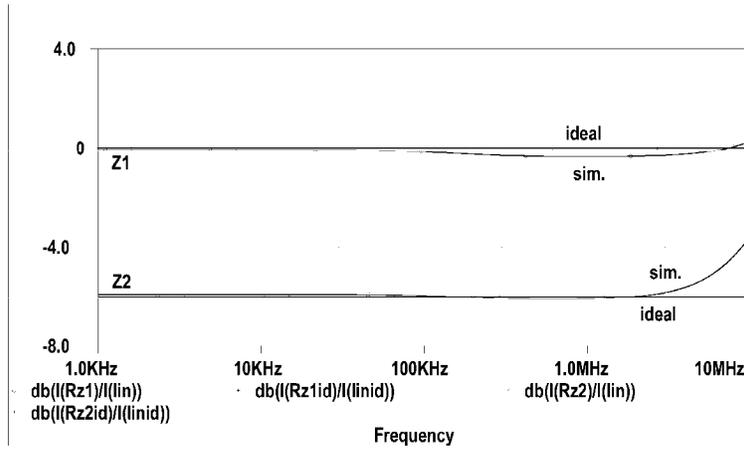
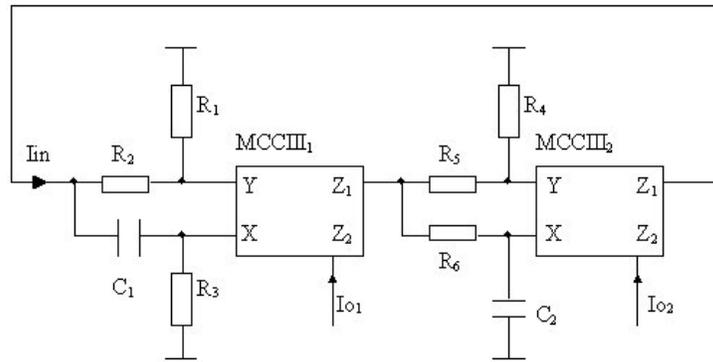
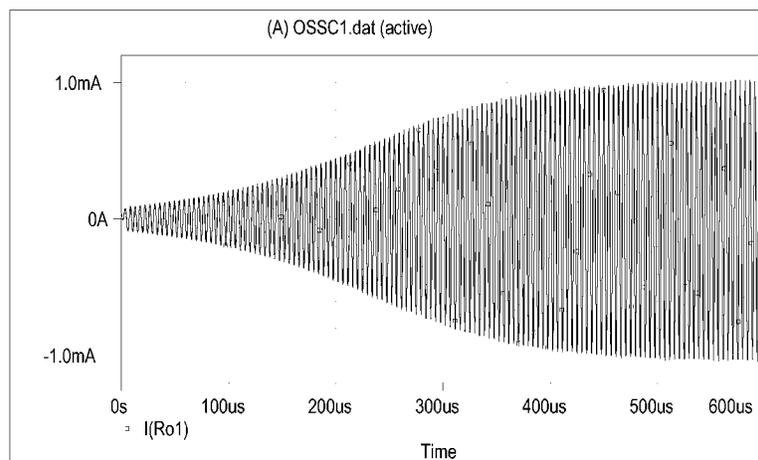


Figure 4. Magnitude and Phase characteristics of allpass section of Fig 2d.



(a)



(b)

**Figure 5. a)** Quadrature Oscillator realized with MCCIIIs,  $R_1=R_3=R_5=R_6=2\text{k}\Omega$ ,  $R_2=R_4=1\text{k}\Omega$ ,

$$C_1=0.5\text{nF}, C_2=1\text{nF},$$

**b)** Output waveforms of the quadrature oscillator

## REFERENCES

- [1] Roberts G. W., Sedra A. S., All current-mode frequency selective circuits, *Electron. Lett.*, vol. 25, pp. 759-761, 1989
- [2] Wilson B., Recent developments in current conveyor and current-mode circuits, *Proc. IEE PT G*, vol. 137, (2), pp. 63-77, 1990
- [3] Toumazou C., Lidgey F.J., and Haigh, D.G.: Analog IC design: the current-mode approach, Peter Peregrinus on behalf of IEE, U.K. 1990.
- [4] Fabre A., Third generation current conveyor: a new helpful active element, *Electron. Letters*, 31, no. 5, pp. 338-339, 1995.

- [5] Liu S. I., Yang Y. Y., Higher-order immittance function synthesis using CCIII, *Electron. Letters*, 32, no. 25, pp. 2295-2296, 1996.
- [6] Horng J.-W. Weng R.-O. Lee M.-H. and Chang C.-W., Universal active current filter using two multiple current output OTAs and one CCIII, *Int. J. Electronics*, Vol. 82, no. 3, 1996.
- [7] Piovaccari A., CMOS integrated third generation current conveyor, *Electron. Letters*, 31, no. 15, pp. 1228-1229, 1995.
- [8] Kuntman H., Cicekoglu O. and Ozoguz S., 'A modified third generation current conveyor, its characterization and applications', *Frequenz*, Vol.56, pp.47-54, 2002
- [9] Tarmy R. and Ghausi M.S., "Very high Q, insensitive active RC networks," *IEEE Trans.Circuit Theory*, vol. CT-17, pp.358-366, Aug. 1970.
- [10] Moschytz, G.S., "A high Q, insensitive active RC network, similar to the Tarmy-Ghausi circuit, but using single-ended operational amplifiers," *Electron. Lett.*, vol. 8, pp. 458-459, Sept. 1972.
- [11] Comer D.T., Comer D.J. and Gonzales J.R., "A high-frequency integrable bandpass filter configuration", *IEEE Trans. Circuits and Systems-II: Analog and Digital Signal Processing*, vol.44, pp.856-861, Oct. 1997.
- [12] Salawu R.I., "Realization of an all-pass transfer function using the second-generation current conveyor," *Proc. of IEEE*, vol. 68, Iss 1, pp. 183-184, 1980.
- [13] Soliman A.M., "Generation of current conveyor-based all-pass filters from op amp-based circuits," *IEEE Trans. Circuits and Systems II: Analog and Digital Signal Processing*, 44, no. 4, pp. 342-330, 1997.
- [14] Bodur, S., "Değiştirilmiş üçüncü kuşak akım taşıyıcı ile yeni olanaklar", M.Sc. Thesis, İstanbul Technical University, Institute of Science and Technology, 2002.