DESIGN OF FIRST-ORDER ALLPASS FILTERS EMPLOYING SINGLE MODIFIED THIRD GENERATION CURRENT CONVEYOR

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Key words: Current Conveyors, Allpass filters

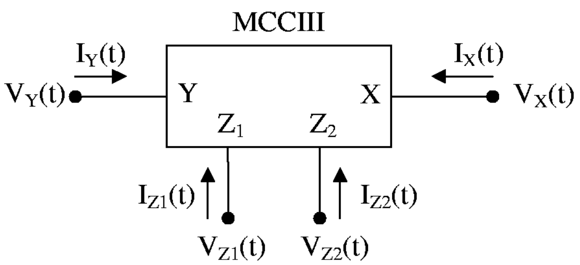
ABSTRACT

Four new first-order allpass filter configurations employing a single modified third-generation current conveyor (MCCIII) is 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.

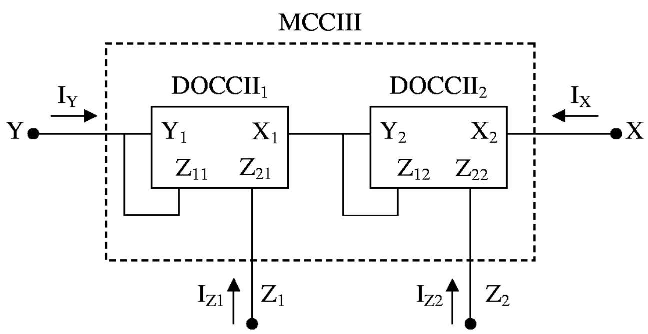
I. INTRODUCTION

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 (CCIIs) and 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].



(a)



(b)

Figure 1. a) Ideal modified third generation current conveyor, b) Realization of the modified third generation current conveyor with two DO-CCIIs.

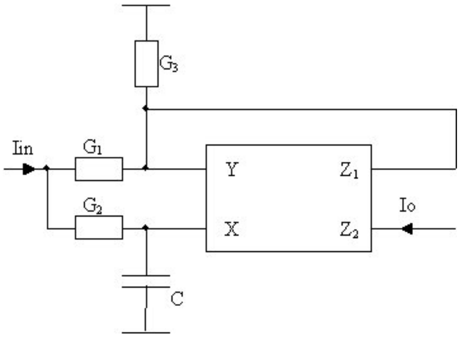
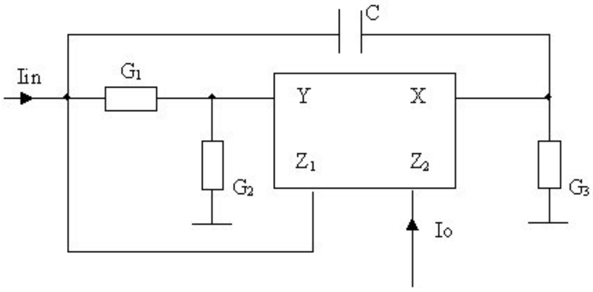
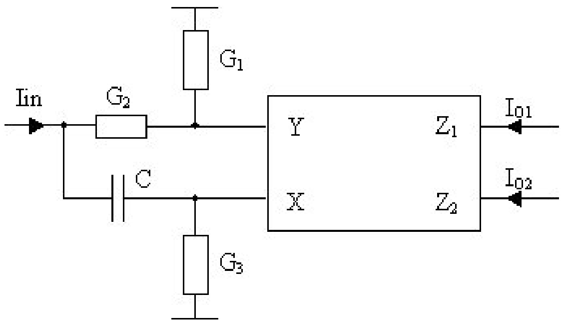
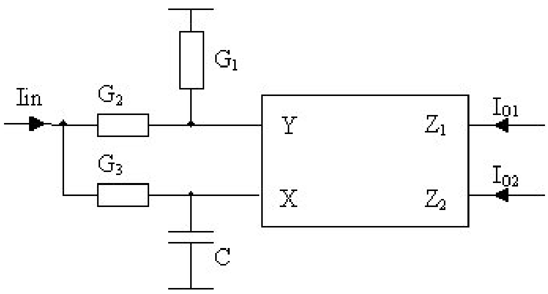
Allpass Filter Topology	Transfer Function
 (a)	$\frac{I_o}{I_{in}} = \frac{1}{(2+k)}\frac{G_3 - sC(1+k)}{G_3 + sC(1+k)}$ for $G_1=G_2(1+k)$
 (b)	$\frac{I_o}{I_{in}} = \frac{-2G_3G_2}{(G_3+G_2)^2}\frac{(G_1G_3 - sCG_2)}{(G_1G_3 + sCG_2)}$ for $k = \frac{G_3{}^2 - G_2{}^2}{2G_3G_2}$
 (c)	$\frac{I_{o1}}{I_{in}} = \frac{k}{2}\frac{G_2 - sC}{G_2 + sC}$ $\frac{I_{o2}}{I_{in}} = -\frac{1}{2}\frac{G_2 - sC}{G_2 + sC}$ for $G_1=G_3$
 (d)	$\frac{I_{o1}}{I_{in}} = -\frac{k}{2}\frac{G_1 - sC}{G_1 + sC}$ $\frac{I_{o2}}{I_{in}} = \frac{1}{2}\frac{G_1 - sC}{G_1 + sC}$ for $G_2=G_3$

Figure 2. Proposed Allpass filter topologies employing single MCCIII.

In this paper, we propose four new first-order allpass filter realisation using the MCCIII. The additional port of the MCCIII provides further design possibilites. 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.

II. 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].:

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

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 $DOCCII_1$ to provide a current gain of k at the port Z_{21}.

III. 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 [11-13]. 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.

In this section, the simulation results of the proposed circuits are given. In the simulations, MCCIIIs are implemented with DOCCIIs illustrated in Fig.3. Note that the emitter resistor ratios R_1/R_3 and R_4/R_6 in $DOCCII_1$ are two times of the corresponding ratios in $DOCCII_2$ to provide the necessary current gain k=2 of the MCCIII [14] .

The supply voltages are taken as ±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.

The passive components are taken as $R_1=R_2=R_3=$ 1kΩ, 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_1which can be considered an advantage of these new active elements

IV. SIMULATION RESULTS

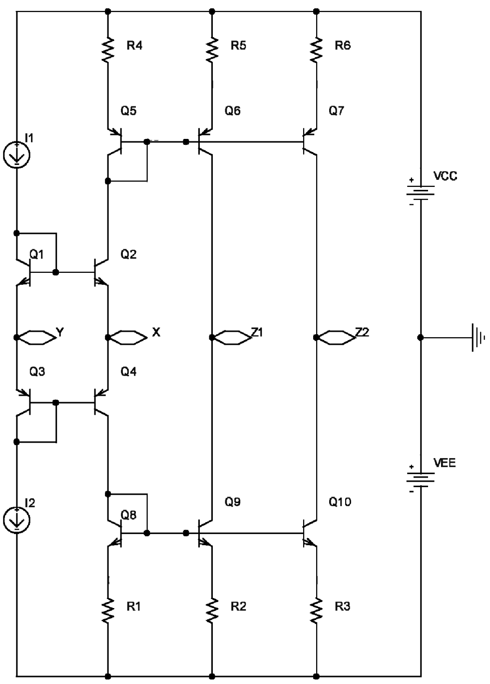


Figure 3. DOCCII used to implement MCCIII

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

$$\varphi_{AP3}(\varpi) = -2.\mathrm{arctg}(\varpi.\tau_1), \qquad \tau_1 = C_1R_2 \quad (2)$$

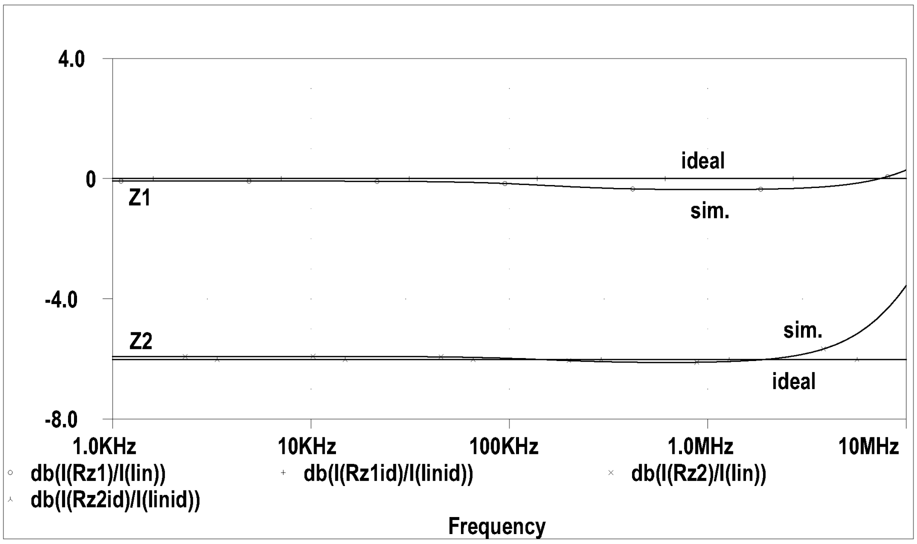
The second allpass circuit yields

$$\varphi_{AP4}(\varpi) = 180 - 2.\mathrm{arctg}(\varpi.\tau_2), \quad \tau_2 = C_2R_4 \quad (3)$$

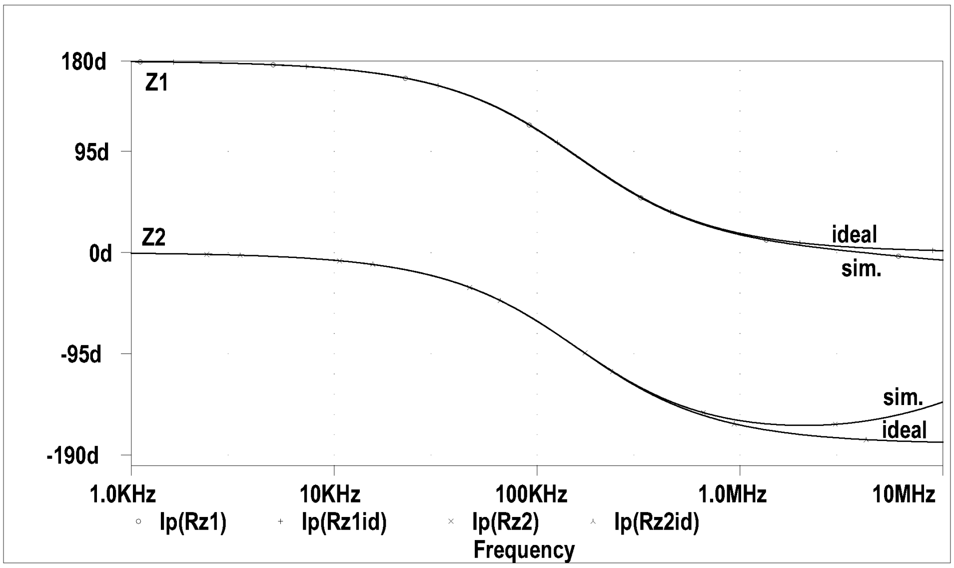
The oscillation frequency of the circuit is obtained as

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

Output waveforms of the quadrature oscillator are given in Fig.5b. From Eq. 4 we obtain an oscillation frequency of fo = 225079Hz. SPICE simulations yield fo = 219768Hz.

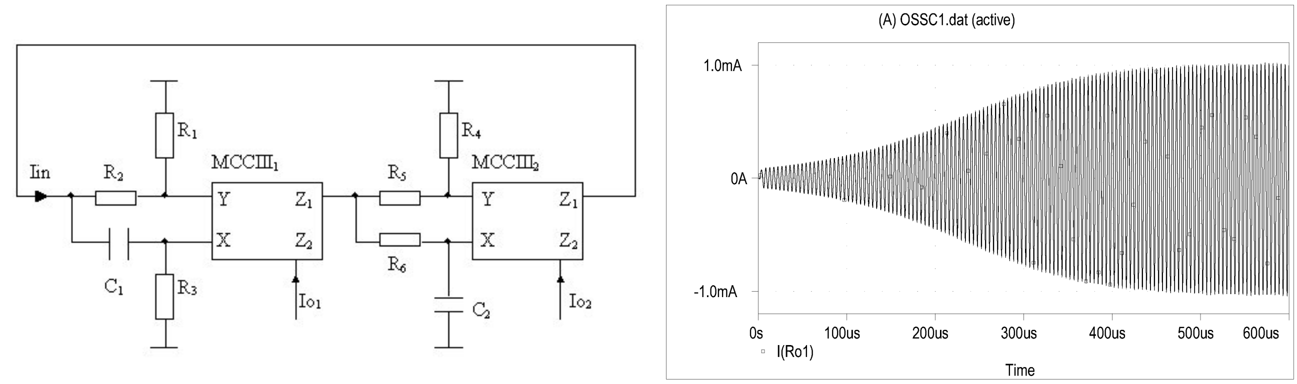


(a)



(b)

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



(a) (b)

Figure 5. a) Quadrature Oscillator realized with MCCIIIs, $R_1=R_3=R_5=R_6=2k\Omega$, $R_2=R_4=1k\Omega$, $C_1=0.5nF$, $C_2=1nF$, b) Output waveforms of the quadrature oscillator

V. CONCLUSIONS

In this study, four first-order allpass filter realisations based on modified third generation current conveyors are presented. A quadrature oscillator realized with MCCIIIs 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.

ACKNOWLEDGEMENT

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

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