

Low Input and High Output Impedances Current-Mode First-Order Allpass Filter Employing Grounded Passive Components

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ABSTRACT

A current-mode low input and high output impedances first-order allpass filter using two multiple output second-generation current conveyors (MOCCIs), one grounded capacitor and one grounded resistor is presented. The suggested filter uses a canonical number of passive components without requiring any component matching condition. The frequency responses simulation results of the proposed filter confirm the theoretical analysis.

Keywords: Second-Generation Current Conveyor; First-Order Filter; Allpass; Current-Mode

1. Introduction

Current conveyors (CCs) are receiving much attention for their potential advantages such as inherent wider signal bandwidths, simpler circuitry and larger dynamic range [1,2]. Current-mode active filters with low input impedance and high output impedance are of great interest because they can be directly connected in cascade to implement higher order filters [3,4]. Besides the use of only grounded capacitor and resistor are beneficial from the point of view of integrated circuit fabrications [5,6]. Several current-mode first-order allpass filters using various active components have been reported. Some circuits use two current conveyors to realize such a first-order allpass filter function with high output impedance [7-9]. However, the passive components they used are not canonical and they require passive components matching conditions [7,8]. Moreover, these circuits [7-9] have not the advantage of low input impedance. The first-order allpass filters [10,11] each uses two current conveyors, one grounded capacitor and one grounded resistor with low input and high output impedances. The first-order allpass filter [12] uses one Z-copy current inverter transconductance amplifier and one grounded capacitor with low input and high output impedances. However, the output terminals of these circuits [10-12] require the connection of two current output terminals. This solution will degrade the final output impedance because of the parallel connection of two individual output impedances [13]. Some first-order allpass circuits

each use one active component [14] were presented. However, these circuits require passive matching conditions and the input impedances of are not low. Some first-order circuits use one active element, one capacitor and one resistor [15-17] were presented. However, these circuits have not the advantage of low input impedance. In 2009, a current-mode first-order allpass filter uses one current differencing transconductance amplifier (CDTA) and one grounded capacitor with low input impedance and high output impedance was presented [18]. As the CDTA is equivalent to the circuit composed of two second-generation current conveyors (CCIs) with a transconductance amplifier [18], the CDTA is a relative complex device with respect to CCII.

In this paper, a new current-mode first-order allpass filter using two multiple output second-generation current conveyors (MOCCIs), one grounded capacitor and one grounded resistor are presented. The proposed circuit has the advantages of low input and high output impedances and without requiring any element matching condition.

The rest of the paper is presented as follows. In Section 2 we present the proposed current-mode first-order allpass filter circuit. Section 3 discusses the active and passive sensitivities of the proposed filter. Section 4 discusses the influences of parasitic elements on the proposed circuit. The frequency responses simulation results are presented in Section 5. Section 6 concludes the paper.

2. Proposed Circuit

Using standard notation, the port relations of a MOCCII

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can be characterized by $v_x = v_y$, $i_{zk} = \pm i_x$ and $i_y = 0$. Considering the proposed current-mode circuit in **Figure 1**, the current transfer function can be expressed as

$$\frac{I_{out}}{I_{in}} = \frac{sCR - 1}{sCR + 1} \quad (1)$$

From (1) it can be seen that a first-order allpass response is obtained from I_{out} . Because the input terminal of the proposed first-order allpass filter is connected directly to the x terminal of MOCCII (1) and the y terminal of MOCCII (1) is grounded, the input terminal has the advantage of low input impedance. Because the I_{out} output terminal is taken out directly from the z_{22+} terminal of the MOCCII (2), the I_{out} output terminal has the advantage of high output impedance. The proposed circuit uses only one grounded resistor and one grounded capacitor, the use of only grounded capacitor and resistor are beneficial from the point of view of integrated circuit fabrications [5,6].

3. Non-Ideality Analysis of the MOCCIIs

Taking into consideration the MOCCII non-idealities, the port relations of MOCCII can be expressed as

$$v_x = \beta v_y \text{ and } i_z = \pm \alpha_k i_x \quad (2)$$

$$\frac{I_{out}}{I_{in}} = \frac{[s(C' - C_{z12}) - (G' - G_a)]G_{x2}}{s^2 C' C_{z12} + s(C'G_{x2} + C'G' + C_{z12}G_a + C_{z12}G_{x2}) + G'G_{x2} + G'G_a + G_aG_{x2}} \quad (5)$$

where $C' = C + C_{z11} + C_{y2} + C_{z21}$, $G' = G + G_{z12}$, $G_a = G_{z11} + G_{y2} + G_{z21}$.

In Equation (5), undesirable factors are yielded by the non-idealities of the MOCCIIs. The effects of capacitance C_{z12} become non-negligible at very high frequencies. To minimize the effects of the MOCCIIs' non-idealities, the operation angular frequency should be restricted to the following condition

$$\omega \ll \sqrt{\frac{G'G_{x2} + G'G_a + G_aG_{x2}}{C' C_{z12}}} \quad (6)$$

5. Simulation Results

HSPICE simulations were carried out to demonstrate the feasibility of the proposed circuit in **Figure 1** using 0.18 μm , level 49 MOSFET from TSMC. The MOCCII was realized by the CMOS implementation in **Figure 3** [20] with the NMOS and PMOS transistor aspect ratios $W/L = 4.5 \text{ u}/0.9 \text{ u}$ and $W/L = 9 \text{ u}/0.9 \text{ u}$, respectively.

Figure 4 represents the magnitude and phase responses of the first-order allpass filters, designed with $f_c = 3.979 \text{ MHz}$: $C = 10 \text{ pF}$ and $R = 4 \text{ k}\Omega$. The power supply was $\pm 1.25 \text{ V}$. The bias voltages are $V_b = -0.6 \text{ V}$.

where $\alpha_k = 1 - \varepsilon_{ki}$ and $\varepsilon_{ki} (|\varepsilon_{ki}| \ll 1)$ denotes the current tracking error, $\beta = 1 - \varepsilon_v$ and $\varepsilon_v (|\varepsilon_v| \ll 1)$ is the input voltage tracking error of a MOCCII. Reanalysis of the filter circuit in **Figure 1** yields the following modified transfer functions:

$$\frac{I_{out}}{I_{in}} = \frac{sCR\alpha_{12}\alpha_{22} - \alpha_{11}\alpha_{22}\beta_2}{sCR + \alpha_{21}\beta_2} \quad (3)$$

The cutoff frequency is obtained by

$$\omega_c = \frac{\alpha_{21}\beta_2}{CR} \quad (4)$$

The active and passive sensitivities are low and obtained as $S_{C,R}^{\omega_c} = -1$; $S_{\alpha_{21},\beta_2}^{\omega_c} = 1$.

4. Influences of Parasitic Elements

A non-ideal MOCCII model is shown in **Figure 2** [19]. It is shown that the real MOCCII has parasitic resistors and capacitors from the y and z terminals to the ground, and also, a series resistor at the input terminal x . Taking into account the non-ideal MOCCII and assuming the circuits are working at frequencies much lower than the corner frequencies of $\alpha_k(s)$ and $\beta(s)$, namely, $\alpha_k \cong \beta \cong 1$. The transfer functions of **Figure 1** become

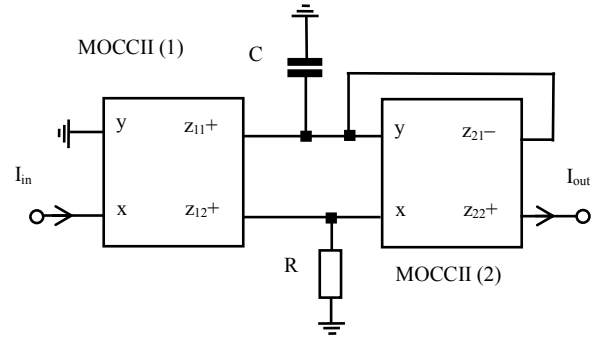


Figure 1. The proposed current-mode first-order filter.

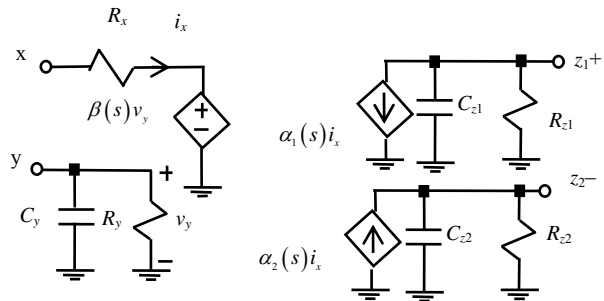


Figure 2. The non-ideal MOCCII model.

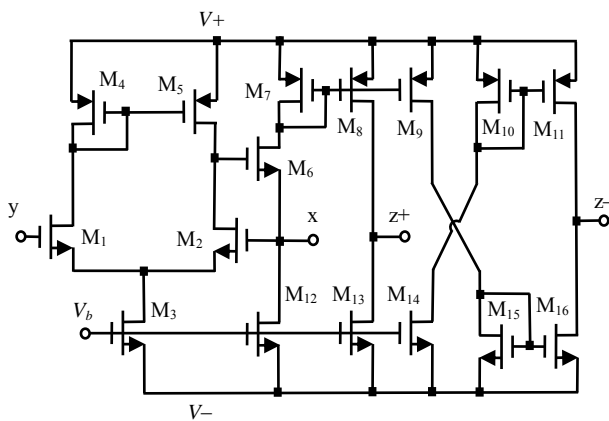


Figure 3. The CMOS MOCCII implementation.

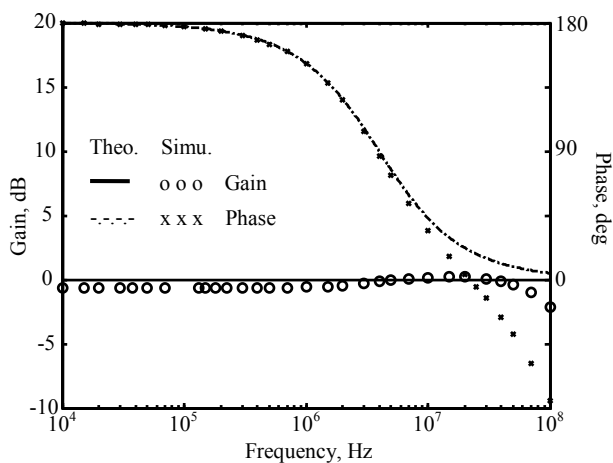


Figure 4. Simulation results of the proposed current-mode first-order allpass filter.

6. Conclusion

A new current-mode first-order filter configuration using two MOCCIIs, one grounded capacitor and one grounded resistor is presented. The proposed circuit has the advantages of low input and high output impedances, using grounded passive components and without requiring any element matching condition.

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