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CCII based more tunable voltage-mode all-pass filters and their quadrature oscillator applications

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ABSTRACT

In this paper, two new voltage-mode (VM) first-order all-pass filters using single active element namely second-generation current conveyor (CCII) and a grounding capacitor are proposed. The first proposed filter employs a dual output CCII (DO-CCII) and the other one uses a modified minus type CCII (MCCII−). One of the main advantages of both configurations is their high input impedances; thus, both can be easily cascaded with other VM circuits. Additionally, the use of a grounded capacitor in both circuits provides suitability for integrated circuit (IC) fabrication process. However, both of the proposed circuits need a single passive component matching constraint. Non-ideality analysis is performed for the proposed circuits. Moreover, two quadrature oscillator applications of the proposed filters are given. The behavior of the filters is verified by SPICE simulations. Also, experimental tests using commercially available ICs (AD844s) are achieved for the second proposed configuration.

1. Introduction

All-pass filters (APFs) [1–32] are widely used in many applications to change the phase of electrical signal while keeping the amplitude of the signal constant. The property of high-input impedance is significant for voltage-mode (VM) active filters. VM APFs can be implemented using various active building blocks (ABBs) such as second generation current conveyor (CCII) which was introduced by Sedra and Smith [33]. The use of CCIIs in some circuit topologies provides high performance and functional versatility [34].

In the literature, there are some VM APF topologies using single ABB [1–7,10,11,15,17,19,21,22,25–32] such as CCII, voltage differencing-differential input buffered amplifier (VD-DIBA), differential buffered and transconductance amplifier (DBTA), voltage differencing inverting buffered amplifier (VDIBA), universal voltage conveyor (UVC), differential voltage current conveyor (DVCC), differential difference current conveyor (DDCC), fully differential current conveyor (FDCCII), differential CCII (DCCII), inverting current differencing buffered amplifier (ICDBA), current controlled current differencing buffered amplifier (C-CDBA), dual-X second-generation current conveyor (DXCCII), differential difference amplifier (DDA), variable gain current conveyor (VGCCII), and inverting voltage buffer (IVB). However, some APFs [5,10,11,15,19–21,26,27,29,31,32] do not have the feature of high input impedance. Also, several APFs [4–6,10,11,19–21,23,29–31] do not contain a grounded capacitor. Some APFs [18,22,23,25] have a capacitor connected in series to the X-terminal of the active device; thus, their high frequency performances are not well [35]. Some APFs [23,25,26] do not employ a canonical number of capacitors (only one). A number of APFs [8,9,12–14,16,18,20,23,24] use more than one ABB. The cascadable APF employing a dual output CCII (DO-CCII) in [1] does not have a resistor connected in series to the X-terminal of the DO-CCII. Another APF configuration using a modified minus-type CCII (MCCII−) does not have a resistor connected in series to the X-terminal of the MCCII−. Therefore, two electronically tunable floating resistors [36] should be replaced instead of resistors of the circuits in [1,2] to control externally. Fortunately, if second-generation current-controlled current conveyors (CCCIIs) [37] are replaced instead of both of the proposed circuits, the resistors connected to the X terminal of the CCCIIs are removed and a floating tunable resistor is replaced instead of each of the other resistors, both of the proposed circuits can be tuned externally.

In this paper, two CCII based VM APF configurations are proposed. One of the proposed APFs uses a DO-CCII and the other one employs a MCCII−. One of the main properties of the proposed APFs is their high input impedances; thus, they can be easily cascaded with other VM circuits. Also, both of the proposed APFs are composed of a grounded capacitor; accordingly, they are suitable for integrated circuit (IC) fabrication [38]. Nevertheless, both of the

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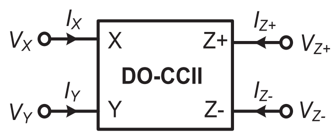

Fig. 1. Electrical symbol of the DO-CCII.

proposed APFs need a single resistive matching condition. Further, two quadrature oscillators derived from the proposed APFs are given as application examples. Non-ideality analysis is performed for the proposed APFs. A number of simulation results are included to confirm to theory. Moreover, experimental test results are given.

The paper is organized as follows: After introduction is given in Section 1, DO-CCII and MCCII− are treated in Section 2. Proposed APF structures are given in Section 3. In Section 4, parasitic impedance effects on the proposed APFs are investigated. As application examples, two quadrature oscillators are given in Section 5. Simulation and experimental test results for the APF topologies are, respectively, given in Sections 6 and 7. In Section 8, some conclusion remarks are given.

2. Circuit description

One of the proposed circuits in this paper employs a single DO-CCII and the other one uses a single MCCII−. Electrical symbol of DO-CCII with four terminals is depicted in Fig. 1. MCCII− with three terminals, which has the current gain (γ) less than unity and greater than zero, can be obtained by grounding Z+ terminal of DO-CCII. Also, the current gain at the Z terminal of the MCCII− can be adjusted by changing relevant aspect ratios of the CMOS transistors of the DO-CCII in Fig. 2 [37].

The DO-CCII can be presented with the following matrix equation:

$$\begin{bmatrix} V_X \\ I_Y \\ I_{Z+} \\ I_{Z-} \end{bmatrix} = \begin{bmatrix} \beta & 0 \\ 0 & 0 \\ 0 & \alpha \\ 0 & -\gamma \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \end{bmatrix} \quad (1)$$

where α and γ are frequency dependent non-ideal current gains and β is frequency dependent non-ideal voltage gain, which are all ideally equal to unity. α, β and γ at sufficiently low frequencies can be presented as $\alpha = 1 - \varepsilon_\alpha$ $(|\varepsilon_\alpha| \ll 1)$, $\beta = 1 - \varepsilon_\beta$ $(|\varepsilon_\beta| \ll 1)$ and $\gamma = 1 - \varepsilon_\gamma$ $(|\varepsilon_\gamma| \ll 1)$ where ε_α and ε_γ are current tracking errors and ε_β is voltage tracking error, which are all ideally equal to zero.

3. The proposed APFs

In this section, two voltage-mode first-order APF structures are introduced. One of them shown in Fig. 3 is implemented by using

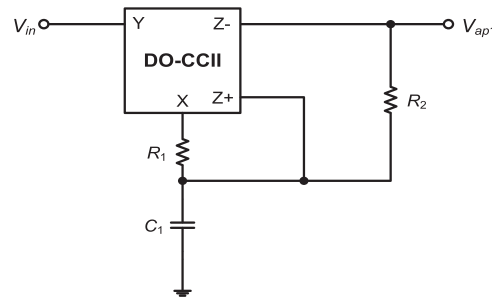

Fig. 3. Circuit schematic of the first proposed all-pass filter.

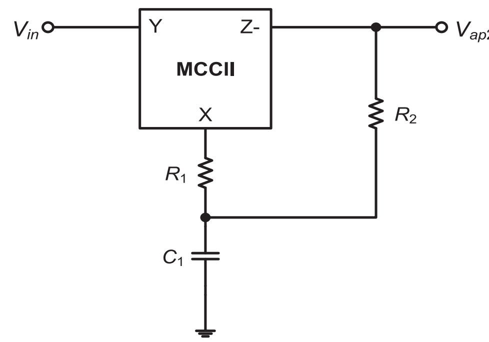

Fig. 4. Circuit schematics of the second proposed all-pass filter.

only one DO-CCII, two resistors ($R_2 = R_1$) and a grounded capacitor (C_1).

Transfer function (TF) of the first proposed filter in Fig. 3 with $R_1 = R_2 = R$ can be ideally written as

$$\frac{V_{ap_1}}{V_{in}} = \frac{1 - sC_1R}{1 + sC_1R} \quad (2)$$

which provides non-inverting all-pass responses. Here, the angular resonance frequency (ω_o) of the first proposed filter is found as $1/(C_1R)$. Also, the phase response is evaluated as follows:

$$\varphi(\omega) = -2\tan^{-1}(\omega C_1 R) \quad (3)$$

where the phase changes from 0° to −180° as the frequency varies from zero to infinity. The TF of the circuit in Fig. 3 with non-ideal gains is obtained as follows:

$$\frac{V_{ap_1}}{V_{in}} = \beta \frac{1 + \alpha - \gamma - s\gamma C_1 R_2}{1 + \alpha - \gamma + sC_1 R_1} \quad (4)$$

Here, the phase response of the proposed filter can also be obtained as

$$\varphi(\omega) = -\tan^{-1}\frac{\omega\gamma C_1 R_2}{1 + \alpha - \gamma} - \tan^{-1}\frac{\omega C_1 R_1}{1 + \alpha - \gamma} \quad (5)$$

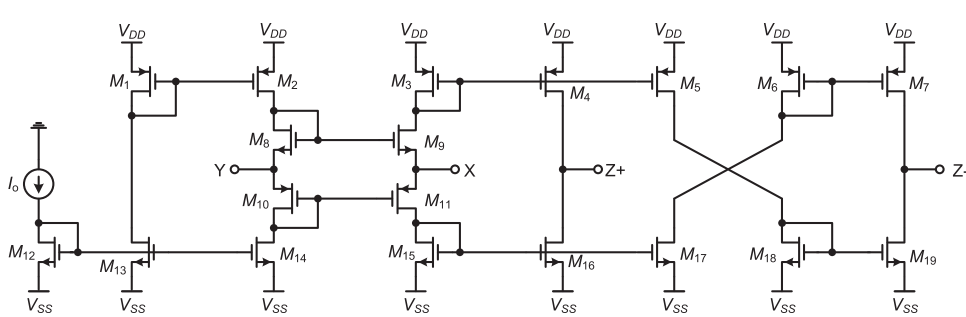

Fig. 2. Internal structure of the DO-CCII [37].