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Current mode first order universal filter and multiphase sinusoidal oscillator

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ABSTRACT

In this article a new current mode first order universal filter with single input and multiple outputs is proposed. The realization uses single dual-X multiple output second generation current conveyor (DX-MOCCII) and two passive grounded components. The presented circuit provides high-pass, low-pass and non-inverting and inverting all-pass responses simultaneously, all at different high impedance outputs. The realized circuit does not require any component matching constraint and all the sensitivities are found low. As an application the non-inverting all-pass filter is cascaded in a close loop with the current mode non-inverting integrator to design a current mode multiphase sinusoidal oscillator (MSO) having six phases. Voltage mode six phase sinusoidal oscillator is also achieved by resistively loading the current mode outputs. The analysis such as phase noise, non-ideality, stability and Monte Carlo are presented and discussed. The presented theory and its results are validated using 0.25 μm process parameters of TSMC in PSPICE simulator.

1. Introduction

In many analog signal processing applications, the use of filter is found to be one of the mandatory building blocks. Among the various orders of filters, the first order filters are widely used in video, audio, communication, instrumentation and many other applications where less power consumption and circuit simplicity are of prime concern. A number of first order filters are available in the literature using op-amp in [1–4] and references cited therein; however they suffer from the limited gain-bandwidth product and slew rate of op-amp. Nowadays, the design of various current mode (CM) signal processing circuits based on current mode building blocks are receiving increasing attention due to wider signal bandwidth, greater linearity, large dynamic range, low power consumption, higher slew rate and simple circuitry in comparison to voltage mode counterparts [5]. In view of these advantages of CM circuits, a number of first order filter circuits using different current mode analog building blocks have been reported in [6–23] and references cited therein. A critical review of these literatures reveals some important features as follows. The circuit in [6] uses a single differential voltage current conveyor (DVCC), two MOSs and one capacitor to implement low pass (LP) and high pass (HP) filter responses. The circuit in [7] also implements only LP and HP responses using one second generation current conveyor (CCII), two resistors and one capacitor. However all the passive components are not grounded. The structures in [8–10] implement only all pass (AP) filter using two active building blocks and one capacitor. Although they offer high output impedance, but suffer from using floating capacitor. The circuits in [11–16] possess only all pass response and use 2–4 passive components in count. Moreover, the structures in [11,15,16] possess floating passive components and in addition [11,12,14] require passive component matching constraints. Although the filter circuit in [17] uses one current conveyor transconductance amplifier (CCTA) and one capacitor, it lacks realization of non-inverting all pass filter and also has low operating frequency. The circuits in [18,19] realize LP, HP, AP (both inverting and non-inverting) using one analog building block and 2 and 3 passive components in count in [18,19] respectively. Moreover, all the filter responses are not available simultaneously in [18,19] and additionally [18] needs passive component matching. The structures in [20–22] implement LP, HP and non-inverting AP using multiple outputs CCII/DXCCII. Moreover, all the passive components are not grounded in [22] and component matching is required in [21]. The above critical review motivated the authors to work further in this area and propose a new circuit for first order universal filter.

It is well known that one of the important applications of the first order all pass filter is the implementation of sinusoidal

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oscillators/multiphase sinusoidal oscillators (MSO). Multiphase sinusoidal oscillators (MSO) provide sinusoidal outputs having different phase shifts such as 45°/90°/180°. They are useful for many applications such as, in control system, radar, spectrum analysis, computers, faults finding in various electronic gadgets, in telecommunications as single-sideband modulator and quadrature mixers and in measurement purposes as selective voltmeters and vector generators [23]. A substantial number of MSO/QOs are reported in the literatures [9–11,13,15–18,20,21,23–30], which are implemented using different design methods. Study reveals that the circuits in [9,13,16–18,20,21,25] are designed by forming a closed loop using inverting/non-inverting all-pass filter with inverting/non-inverting lossless integrator respectively. MSO circuit is discussed in [10] by cascading all pass filter with inverting gain amplifier in feedback path. The MSO/QOs in [11,15] are designed by using one each non-inverting and inverting all-pass filter. An n phase MSO [24] using current backward transconductance amplifier (CBTA) is designed by cascading lossy integrators with an inverting amplifier. The structure [27] uses one lossy integrator and an inverting lossless integrator in a close loop. A second order universal filter in a close loop with a negative resistor is used in structure [29] to realize a quadrature oscillator (QO).

This paper presents a new CM first order universal filter, which provides high-pass, low-pass, non-inverting and inverting all-pass responses simultaneously with single input and multiple outputs without any matching constraint. Moreover, it uses only single dual-X multiple output second generation current conveyor (DX-MOCCII) with one each grounded capacitor and resistor. As an application, a six phase current-mode sinusoidal oscillator is designed using the proposed filter. The effects of non-ideality of the DX-MOCCII on the transfer function of the proposed filter are also examined. The proposed universal filter and oscillator circuits are simulated using PSPICE simulator to validate the theoretical proposition.

The organization of the paper starts with this Section 1 where introduction is given. In Section 2, the first order universal filter is proposed followed by Section 3 wherein the design of multiphase sinusoidal oscillator (MSO) is discussed. The phase noise analysis of MSO is discussed in Section 4. The effects of non-ideality of DXCCII on both filter and MSO are discussed in Section 5. The stability of the filter has also been analyzed and discussed using non-ideal voltage and current transfers of DX-MOCCII in Section 6. The comparison of the proposed universal filter and MSO is discussed with the available literatures in Section 7 followed by simulation and conclusion in Sections 8 and 9 respectively.

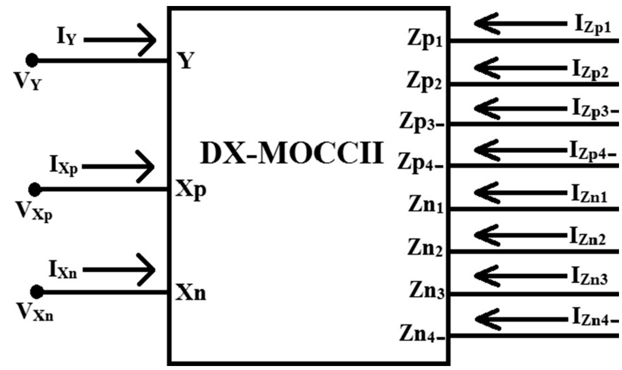

Fig. 1. Symbolic representation of DX-MOCCII.

2. Proposed first order universal filter realization

The following matrix represents the characteristics of DX-MOCCII.

$$\begin{bmatrix} I_Y \\ V_{Xp} \\ V_{Xn} \\ I_{Zpi\pm} \\ I_{Znj\pm} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ -1 & 0 & 0 \\ 0 & \pm 1 & 0 \\ 0 & 0 & \pm 1 \end{bmatrix} \begin{bmatrix} V_Y \\ I_{Xp} \\ I_{Xn} \end{bmatrix}, \quad \text{where i, j} = 1,2,3,4. \tag{1}$$

The electrical symbolic representation and internal CMOS structure of DX-MOCCII are given in Figs. 1 and 2 respectively [31,32].

Proposed first order CM universal filter using single DX-MOCCII, single grounded capacitor and resistor is shown in Fig. 3.

Analysis of the circuit by assuming ideal DX-MOCCII gives the following current transfer functions at different high impedance output terminals.

$$\frac{I_{LP}}{I_{in}} = -\frac{1/RC}{s + 1/RC} \tag{2}$$

$$\frac{I_{HP}}{I_{in}} = -\frac{s}{s + 1/RC} \tag{3}$$

$$\frac{I_{AP+}}{I_{in}} = \frac{s - 1/RC}{s + 1/RC} \tag{4}$$

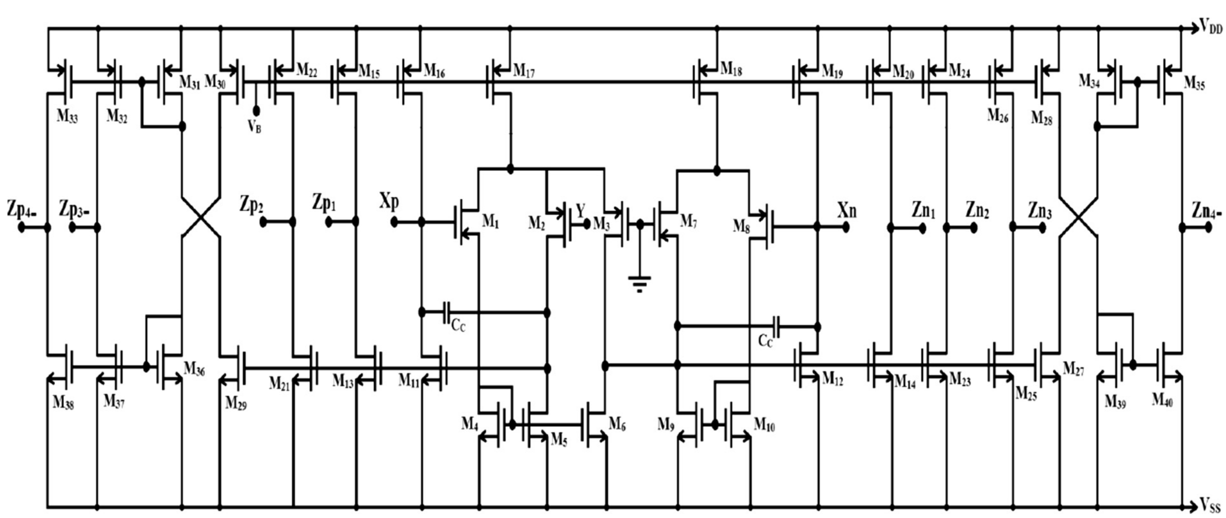

Fig. 2. Internal CMOS structure of DX-MOCCII.