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Design of Current Mode SIMO Filter using EXCCTA

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Abstract
This paper presents, a new single input multi output (SIMO) filter that works in current mode (CM). The universal filter is designed using a extra x current conveyor transconductance amplifier (EXCCTA). The design employs two EXCCTAs and two grounded capacitors. The design can provide all the five responses i.e., high-pass (HP), band-pass (BP), low-pass (LP), all-pass (AP), and band-stop (BS) simultaneously. In addition, it provides an independent electronic tunability of angular frequency (ω) and quality factor (Q). Moreover, there is no requirement of passive component matching. The simulation results are obtained using spice software employing 0.18 µm CMOS technology at a supply voltage of ±0.9V. The proposed filter is tested at a frequency 7.054MHz.

Keywords: *Analog circuits, Current mode, Current conveyor, Signal processing*

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I. INTRODUCTION

Filters are an integral part of almost every electronicsystem and so their synthesis and developmentremain an ever-evolving field. Among various filterstructures universal filters are the most versatile as allthe standard filter functions can be derived from them[1]. They serve as standalone solution to manyfiltering needs.Owning to their inherent advantage of widebandwidth, high slew rate, low power consumption,simple circuitry, and excellent linearity [2-3] currentconveyors (CC) are widely used in electronic design.Moreover, the requirement of low voltage low poweroperation put forward by portable electronic devicesand the energy harvestingsystems [4-5] etc. furtherencourages the use of CC. The current controlledcurrent conveyor (CCCII) is the most versatile activeelement due to its electronically tunable parasiticresistance [6]. Numerous filter implementationsutilizing CCCII can be found in the open literature[6]. The universal filter structure can be regarded asthe most flexible as it can realize all the standardfilter functions without any alteration in its topology.In the present-day mixed mode design environmentwhere many systems interact many times the needarises for the current mode and voltage mode circuitsto be connected. This requirement can bemet by employing trans-admittance mode (TAM) andtrans-impedance mode (TIM) filter structures whichcan serve as the interface providing distortion freeinteraction. Although several TAM and TIMfilter structures can be found in the literature [7] but asingle topology providing the CM, VM, TAM andTIM responses will be an added advantage in termsof area and power requirements. In the past twodecades, anumber of mixed mode filters have beenproposed utilizing different current mode activeelements like dual output current controlled currentconveyor (DOCCCII), multi output current conveyor(MOCCII) [6], current controlled current conveyortransconductance amplifier (CCCCTA) [6], Currentfeedback operational amplifiers (CFOA) [6], fullydifferential current conveyor (FDCCII) [6],differential difference current conveyor and digitallyprogrammable current conveyor (DPCCII)[6]etc.Many reported universal structures useseveral active and passive elements like the onereported by [9] with six CCII, oneDOCCII,eight resistors and two grounded capacitors.The filter is able to realize all filter function in four modes. The same author [10] presented anothermixed mode universal filter employing fourDOCCCII and two capacitors. Although the activeand passive elements are halved compared to theprevious design but still the structure was not able torealize all pass response in any mode. The authors in [11] proposed single input multi output (SIMO)filter employing three CCCCTAs and two groundedcapacitors. The circuit is capable of realizing HP, LPand BP responses in all four modes. Additionally, thefilter can realize low pass notch (LPN), high passnotch (HPN) and AP responses in CM and TAMmodes of operation. In [12]proposed a CM and TIM mode nth order filter usingMOCCII realizing all standard filter functions. Thefilter required (n+1) MOCCII, (n+1) resistors and ngrounded capacitors for realization. For therealization of second order response the filterstructure would require three MOCCII, three resistorsand three capacitors which will result in large areaand increased power dissipation. In [13] proposed a

CM and VM mode universal filterrealizing all standard functions in both the modes.The multi input single output (MISO) structureemploys two DOCCCII and two capacitors. The circuit also has the independent tuning capability.In [14] presented a mixed mode universalfilter employing one DOCCCII, one MOCCCII, tworesistors and two capacitors. The circuit can realize all the standard filter functions in the fourmodes with electronic tunability.

Literature shows there are many tunable variants of current conveyorcircuits i.e. current conveyor transconductance amplifier(CCTA) [18], current follower transconductance amplifier(CFTA) [19], current controlled current conveyortransconductance amplifier (CCCCTA) [16-18], extra x current conveyor transconductance amplifier (EXCCTA) [20] etc.

In thiswork a resistor less SIMO universal filter is designed. The filter is designed using EXCCTA active block. The filter can provider all five filter functions simultaneously.

II. Extra X Current Conveyor Transconductance Amplifier (EXCCTA)

The extra x current conveyor transconductance amplifier (EXCCTA) is functionally an improved and more versatile version of extra x current conveyor (EXCCII). The EXCCTA[20] includes features of current and voltage followers and operational transconductance amplifier (OTA) making it more versatile. The voltage current (V-I) characteristics of the developed EXCCTA are given in Equations (1-5) and the block diagram is presented in Figure 1.

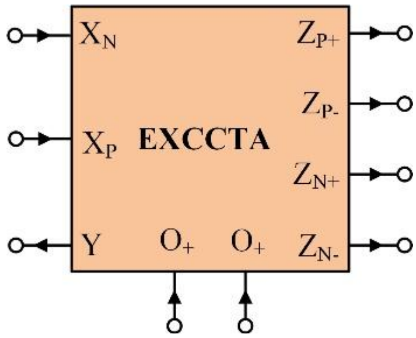

Figure 1. Block Diagram of EXCCTA

$$V_{XP} = V_{XN} = V_Y \quad (1)$$

$$I_{XP} = I_{ZP+} = I_{ZP-} \quad (2)$$

$$I_{XN} = I_{ZN+} = -I_{ZN-} \quad (3)$$

$$I_{O+} = g_m (V_{ZP+}) \quad (4)$$

The expression for transconductance (g_m) is given in Equation 5.

$$g_m = \sqrt{\mu_n C_{OX} \frac{W}{L} I_B} \quad (5)$$

where C_{OX} is the gate oxide capacitance, μ_n is the mobility of electrons in NMOS, g_m denotes the transconductance of OTA set via bias current I_B and $\frac{W}{L}$ is the aspect ratio of the transistors.

The CMOS implementation of the EXCCTA is presented in Figure 2. The Y terminal is high impedance voltage input node and X_P& X_N low impedance voltage output/current input nodes. The O_+, Z_{P+}& Z_{N+} terminals are high impedance current output nodes. The number of current output terminals (I_{ZP+}, I_{ZP-}, I_{ZN+}, I_{ZN-}, O_+, O_-) can be increased by simply adding two MOS transistors.

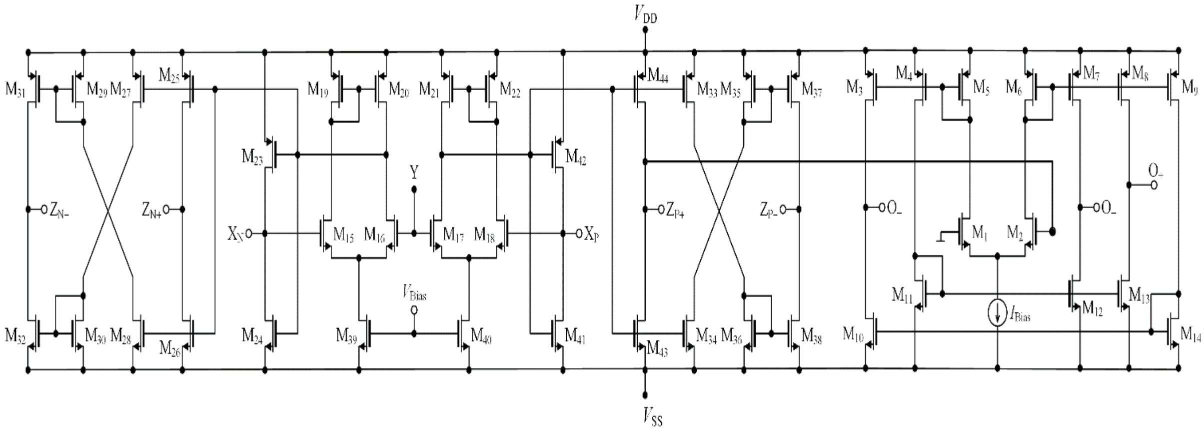

Figure 2 CMOS implementation of EXCCTA

III. Current Mode Filter

The proposed resistor less SIMO CM filter is shown in Figure 3. The filter employs only two grounded capacitors and can realize LP, BP and HP responses simultaneously. The NP and AP response can be obtained by summing the HP, BP and LP responses. All the responses are available at high impedance nodes. The features of the filter include use of only two active elements, only two grounded capacitors, requirement of no matching condition, availability of high output impedance. and tunability. The filter transfer function and expression for pole frequency and quality factor are given in Equations (6-12).

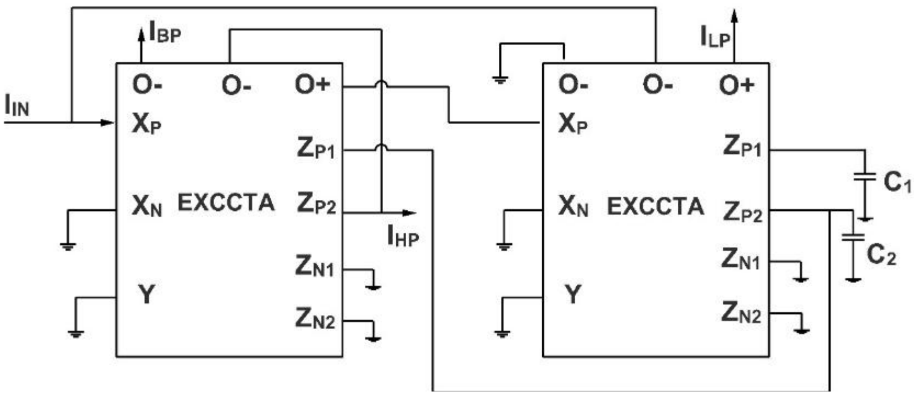

Figure 3: Resistor less SIMO CM universal filter

$$\frac{I_{HP}}{I_{IN}} = -\frac{-S^2C_1C_2}{S^2C_1C_2 + SC_1g_1 + g_1g_2} \tag{6}$$

$$\frac{I_{LP}}{I_{IN}} = -\frac{-g_1g_2}{S^2C_1C_2 + SC_1g_1 + g_1g_2} \tag{7}$$

$$\frac{I_{BP}}{I_{IN}} = +\frac{SC_1g_2}{S^2C_1C_2 + SC_1g_1 + g_1g_2} \tag{8}$$

$$\frac{I_{NP}}{I_{IN}} = \frac{-S^2C_1C_2 - g_1g_2}{S^2C_1C_2 + SC_1g_1 + g_1g_2} \tag{9}$$

$$\frac{I_{AP}}{I_{IN}} = \frac{-S^2C_1C_2 - g_1g_2 + SC_1g_2}{S^2C_1C_2 + SC_1g_1 + g_1g_2} \tag{10}$$

$$f_o = \frac{1}{2\pi}\sqrt{\frac{g_1g_2}{C_1C_2}} \tag{11}$$

$$Q = \sqrt{\frac{g_2C_2}{g_1C_1}} \tag{12}$$

From equation (11) to (12), it is very clear that we can independently tune the quality factor of the filter without affecting the frequency (f) which means that f and Q are independently tunable.

IV. RESULT AND DISCUSSION

To verify the filter the EXCCTA is designed for a supply of ±0.9V using 0.18μm CMOS technology. The CM filter is designed for -3dB cutoff frequency of 7.054MHz by selecting C_1=20pF andC_2=20pF. The resulting quality factor of the filter is found to be 1.29. The response of the filter is presented in Figure 4. The response of the AP filter is given in Figure 5. The simulated pole frequency of the is found to be 6.898MHz which translates in to 3.8% error this is due to parasitic elements and non-ideal effects present in the EXCCTA.

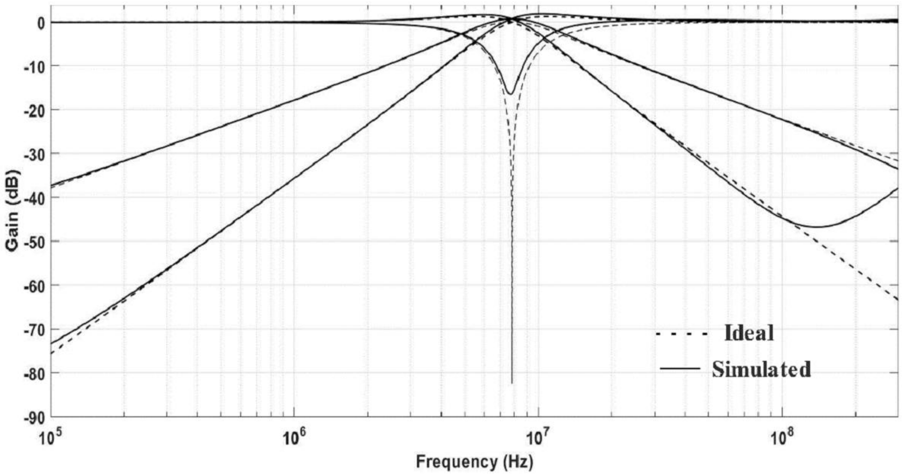

Figure 4: Ideal and simulated characteristics of the SIMO CM filter

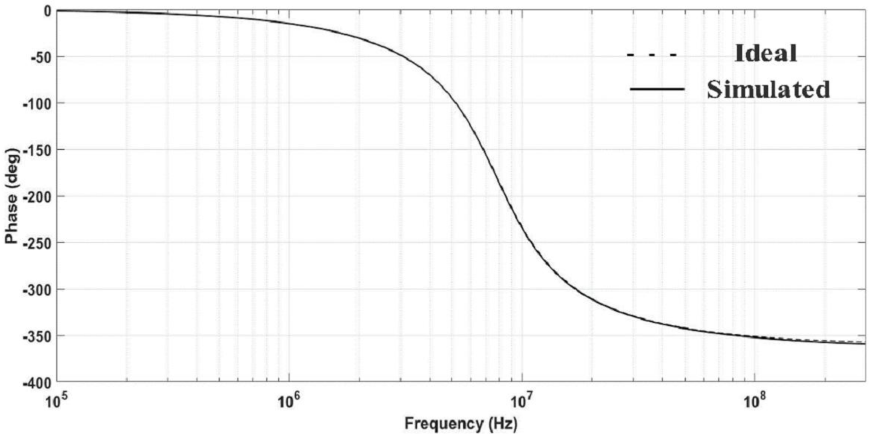

Figure 5: Simulated and ideal phase characteristics of the SIMO CM AP filter

The quality factor of the proposed filter can be tuned independent of the pole frequency by changing the bias current of the OTA as seen in Figure 6. The THD of the filter for band pass configuration is also calculated which is found to be perfectly within acceptable limit of 5% for wide input current range of up to 80μA.

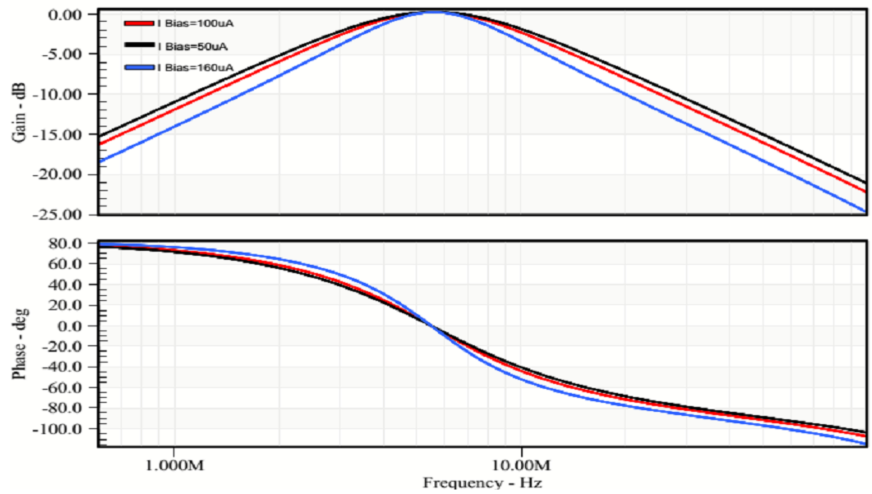

Figure 6: Quality factor tuning for BP configuration

To investigate the signal processing capabilities of the filter transient analysis is also performed for the BP configuration. A 50µA input signal at 7.054 MHz frequency is applied and the output is observed It can be inferred from the Figure 7 that the filter can process signals with minimum distortion.

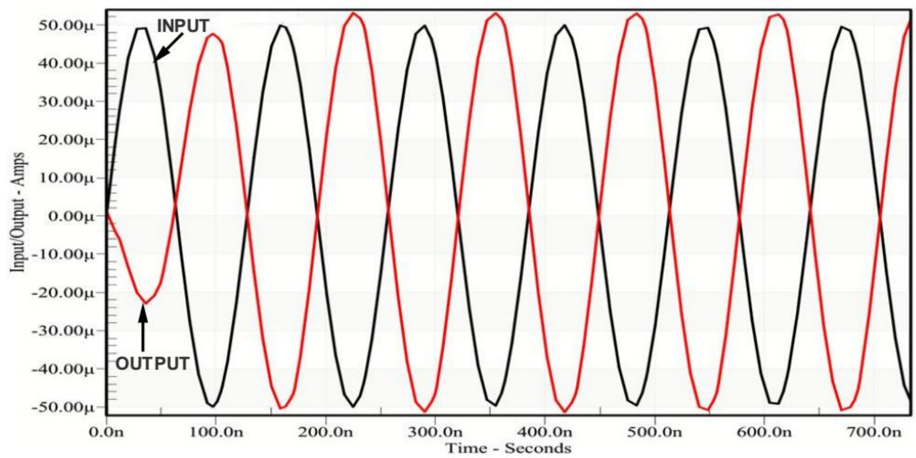

Figure 7: Phase response of the AP configuration

V. CONCLUSION

A resistor less current mode SIMO filter is designed using extra x current conveyor transconductance amplifier (EXCCTA) block. The filter employs only two grounded capacitors making it a resistor less. The filter required no passive component matching for response realization. The filter works at a supply of ±0.9V and at a frequency of 7.054MHz. The theoretical and simulation results closely follow each other.

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