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A Voltage mode biquad with lowpass, bandpass and notch outputs using Voltage Differencing Current Conveyor

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Abstract: The present work deals with voltage differencing current conveyor and its application in analog circuit design. There have been several major developments in the area of analog circuits which have taken place during the past four decades. There is a bulk of material available about the various active blocks developed past Current Conveyors.Among various modern active building blocks, Voltage Differencing Current Conveyor(VDCC), is emerging as quite flexible and versatile building block for analog circuitdesign. In this paper an attempt has been made to highlight the realization of the VDCC active block using MOSFETs and a VDCC based biquad filterusing three active blocks has also been realized. This VDCC based voltage mode biquad filter gives low-pass, band-pass and notch outputs. The workability of the circuit is supported by PSPICE simulations using TSMC 0.18µm parameters.

Keywords: voltage differencing current conveyor, biquad filter, low-pass, band-pass, notch

I. INTRODUCTION

In the past many circuits for the simulation of voltage mode biquadsusing different active building blocks such as operational amplifiers, current conveyors, current feedback amplifiers, current differencing buffered amplifiers, current differencing transconductance amplifiers, operational transconductance amplifiers, operationalmirrored amplifiers, voltage differencing differentialinput buffered amplifiers, and voltage differencingtransconductance amplifier have been reportedin the literature.

In recent times, many active building blocks have been presented, and VDCC is one of them [5]. The usefulness of recently introduced active building block "VDCC" is well-defined in [1]. In [1], the authors proposed a MOSFET model for realization of VDCC active block and then realized grounded inductance simulator circuits using single VDCC and two passive components.

The objective of this paper is to propose a multifunction filter based on two integrator loop topology first proposed by Kerwin Heulsman and Newcomb (KHN) which is realized using VDCC as the active analog block. First of all the VDCC block was realized using MOSFETs[1] and then using three VDCC blocks and some passive elements the biquad filter was realized.

II. VOLTAGE DIFFERENCING CURRENT CONVEYOR

The circuit symbol of the recently proposed active element,VDCC, is shown in Fig. 1, where p and n are input terminals andz, x, $W_p$and $W_n$are output terminals.

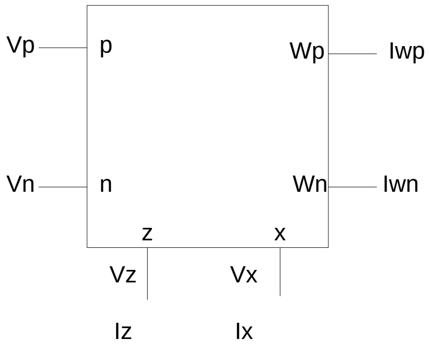

Fig.1: Symbol of VDCC

All of the terminals exhibithigh impedance, except the x terminal.Using standard notation, the port relations of an ideal VDCCshown in Fig. 1, can be characterized by[2]

$$\begin{bmatrix} I_n \\ I_p \\ I_z \\ V_x \\ I_{Wp} \\ I_{Wn} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ g_m & -g_m & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} V_p \\ V_n \\ V_z \\ I_x \end{bmatrix}$$

According to the above matrix equation, the first stage can be realized by a balanced transconductance amplifier to convert thedifference of the input voltages ($V_p - V_n$) into the output current (I_z)with transconductance gain of $g_m$and the second stage is a currentconveyor used for transferring x-terminal current to $W_p$and W_n terminals. For a balanced CMOS transconductance amplifier,the parameter $g_m$can be given as

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$$g_m = \sqrt{I_{B1}\mu_n C_{ox}\left(\frac{W}{L}\right)_1}$$

where $\mu_n$is the mobility of the carrier for NMOS transistors, C_{ox}isthe gate-oxide capacitance per unit area, W is the effective channelwidth, L is the effective channel length and $I_{B1}$is bias current.

III. THE PROPOSED VDCC BASED MULTIFUNCTION BIQUAD FILTER

The block diagram of the proposed voltage mode multifunction biquad filter is shown in fig. 2 which contains two lossless integrators, one summer and proportional gain blocks. It is similar in configuration to the filter based on CCII proposed in [3]. In this, most important thing is that all the passive elements are used as grounded elements [4]. So, it is easy to fabricate in the form of IC.

By analysis of the circuit shown in fig.2, the transfer function expressions are given as

$$\frac{V_{out\,1}}{V_{in}} = \frac{\frac{G_1 G^2}{C_1 C_2 (G_1+G-G_2)}}{D(s)} \quad (1)$$

$$\frac{V_{out\,2}}{V_{in}} = \frac{\frac{-sG_1 G}{C_2 (G_1+G-G_2)}}{D(s)} \quad (2)$$

$$\frac{V_{out\,3}}{V_{in}} = \frac{\frac{s^2}{(G_1+G-G_2)} + \frac{G_1 G^2}{C_1 C_2 (G_1+G-G_2)}}{D(s)} \quad (3)$$

$$D(s) = s^2 + \frac{G^2}{C_1(G_1+G-G_2)}s + \frac{G^2}{C_1 C_2} \quad (4)$$

From equations (1)-(4) it can be seen that a lowpass response is obtained from $V_{out\,1}$, a bandpass response is obtained from $V_{out\,2}$and a notch response is obtained from$V_{out\,3}$.

The proposed circuit uses three VDCCs, two grounded capacitors and eight resistors.

The design methodology of using only grounded capacitors is attractive, because grounded capacitor can be implemented on a smaller area than the floating counterpart and it can absorb equivalent shunt capacitive parasitics [6-8].

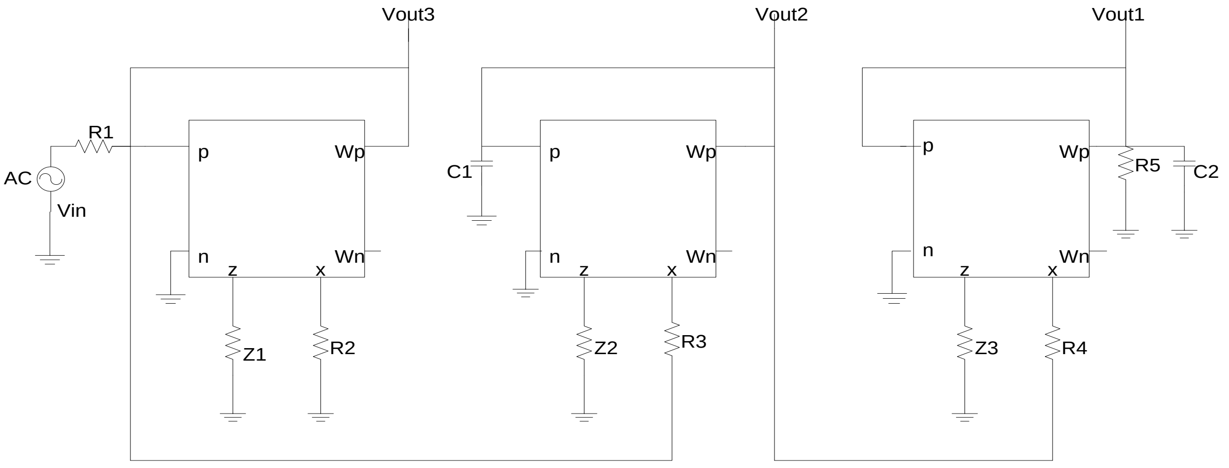

Fig: 2: Block Diagram of Proposed Biquad Filter

In all cases, the resonance angular frequency ωo and the quality factor Q are given by

$$w_0 = G\sqrt{\frac{1}{C_1 C_2}} \quad (5)$$

$$Q = \frac{(G_1+G-G_2)}{G}\sqrt{\frac{C_1}{C_2}} \quad (6)$$

The resonance angular frequency can be controlled by G. The quality factor can be orthogonally controlled by $G1$ or $G2$.

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IV. SENSITIVITY ANALYSIS

The sensitivities of the proposed circuit are given as:

$$S_G^{w_0} = 1 \; ; \; S_{C_1}^{w_0} = S_{C_2}^{w_0} = -\frac{1}{2}$$

$$S_{G_1}^{Q} = \frac{G_1}{G + G_1 - G_2} \; ; \; S_{G_2}^{Q} = \frac{G_1}{G + G_1 - G_2}$$

$$S_G^{Q} = \frac{-G_1 + G_2}{G + G_1 - G_2}$$

$$S_{C_1}^{Q} = -S_{C_2}^{Q} = \frac{1}{2}$$

V. SIMULATIONS

The proposed circuit was simulated using PSPICE. The VDCC was implemented using the MOSFET model proposed in [1] using TSMC 0.18µm parameters. Thesupply voltages are chosen as ± 0.9 V. The following setting was selected to obtain the lowpass, bandpass andnotch filters: $R1 = R2 = R3 = R4 = R5 = 1\text{k}\Omega$, $C1 = C2 = 1\text{nF}$with $Q = 1$ and f_o= 159.15 KHz. Figs. 3 and 4represent the simulated frequency responses for thelowpass (*Vout*1), bandpass (*Vout*2) and notch (*Vout*3) filtersoffig.2, respectively. While fig. 3 shows the low-pass, band-pass and notch responses, fig.4 shows the phase response for the three outputs. The simulation results are coherentwith the theoretical analyse

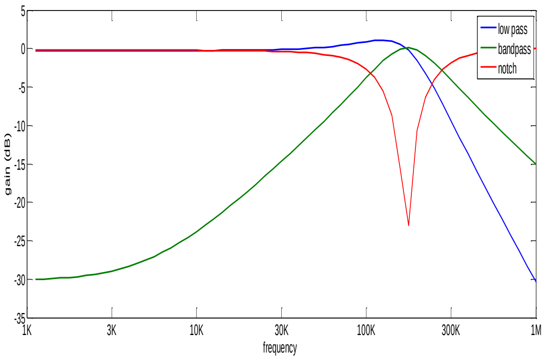

Fig.3 Magnitude response of the proposed biquad filter showing low-pass, band-pass and notch outputs

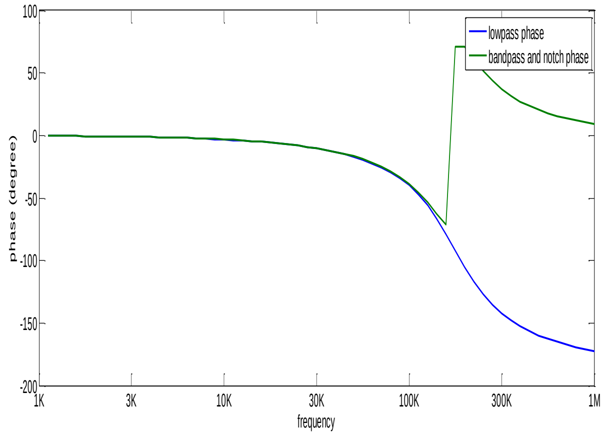

Fig.4 Phase response of the proposed biquad filter

VI. CONCLUSIONS

In this paper, a new single input and three outputs voltage-mode biquadratic filter is presented. The proposed circuit uses three VDCCs, two grounded capacitors and eight resistors. The new circuit offers several advantages, such as the realization of lowpass, bandpass, and notch filter functions, simultaneously, in the same circuit configuration; the use of only three VDCCs; orthogonally controllable resonance angular frequency and quality factor and the use of only grounded capacitors.

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