A TRANSIMPEDANCE TYPE MULTIFUNCTION FILTER SUITABLE FOR MOSFET-C TECHNOLOGY

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ABSTRACT

In this paper, a transimpedance-mode multifunction filter is proposed. The proposed circuit employs three differential voltage current feedback amplifiers (DVCFAs) as active elements together with two capacitors and three MOS resistors, so, it's suitable for MOSFET-C Technology. The central frequency and the quality factor of the filter can be electrically controlled through the gate voltage of two MOS transistors. The circuit simultaneously provides in transimpedance-mode the three basic filter functions, namely bandpass (BP), highpass (HP) and lowpass (LP) functions. The output signals are obtained at low output impedance terminals, which is important for easy cascading with the next stage in voltage-mode operation. SPICE simulation results are given to verify the theoretical analysis.

I. INTRODUCTION

The transimpedance circuit converts input current signal into voltage signal at its output, i.e., an interface circuit connecting a current-mode circuit to a voltage-mode circuit. Transimpedance type signal processing allows accomplishing two steps, i.e. converting into voltage signal and then voltage mode signal processing, simultaneously. By this way, the number of active and passive elements used in such circuits can be reduced significantly. Typical example for this type of circuit is the digital/analog converter (DAC). In this application, one can use a transimpedance (I-to-V) buffer, followed by the active RC filter. However, such an approach results in increased area and power dissipation, as well as worse noise performance. To get the best system performance, it would be desirable to perform the filtering in a transimpedance configuration. Another example is the receiver baseband (BB) blocks of modern radio systems [1], and the transimpedance amplifier that is commonly used in optical receivers [2]-[3].

On the other hand, of the various methods of multifunction filter design, those based upon current conveyors (CC) or their variants, have received more attention [4-10]. Based on the active elements used in the integrator and summer circuits, several multifunction filters have been presented in the literature [8-14] that operate in voltage-mode (VM). To the best knowledge of the author there is a small number of filter topologies operating in transimpedance-mode reported in the literature [15-17].

In this work, we propose a transimpedance-mode multifunction filter circuit, which employs three differential voltage current feedback amplifiers (DVCFAs) [18] as active elements together with two capacitors, two MOS transistors that acts as linear controllable resistors due to the nonlinear cancellation capability of the DVCFA element and another two MOS transistors that acts as a linear controllable resistor. Using only two grounded capacitors, which is minimum number required for a biquadratic filter, and using only three simple electronic resistors, is important in integrated circuit implementation point of view. In addition, the filter circuit has low output impedance, of which the following voltage-mode circuit can be directly connected in cascade with no need to interpose active separating stages. The proposed circuit simultaneously provides the three basic filter functions, namely bandpass (BP), highpass (HP) and lowpass (LP) functions.

II. CIRCUIT DESCRIPTION

The DVCFA [18], whose electrical symbol is shown in Figure 1, is a six-terminal network with terminal characteristics described by

$$\begin{bmatrix} V_X \\ I_{Y1} \\ I_{Y2} \\ I_{Y3} \\ I_Z \\ V_W \end{bmatrix} = \begin{bmatrix} 0 & 1 & -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} I_X \\ V_{Y1} \\ V_{Y2} \\ V_{Y3} \\ V_Z \\ I_W \end{bmatrix} \quad (1)$$

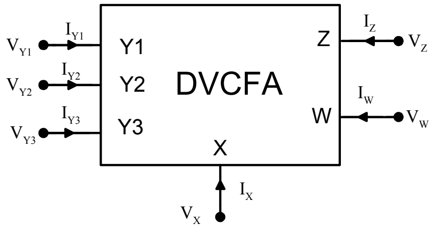

Figure 1: Electrical symbol of DVCFA

The corresponding multifunction filter circuit is illustrated in Figure 2, from which it can be observed that the first stage is a summer circuit and the second and third stages are integrator circuit stages [8]. The circuit employs two MOS transistors that acts as linear controllable resistors (R_1 and R_2) due to the nonlinear cancellation capability of the DVCFA element and another two MOS transistors that acts as a linear controllable resistor (R_{in})

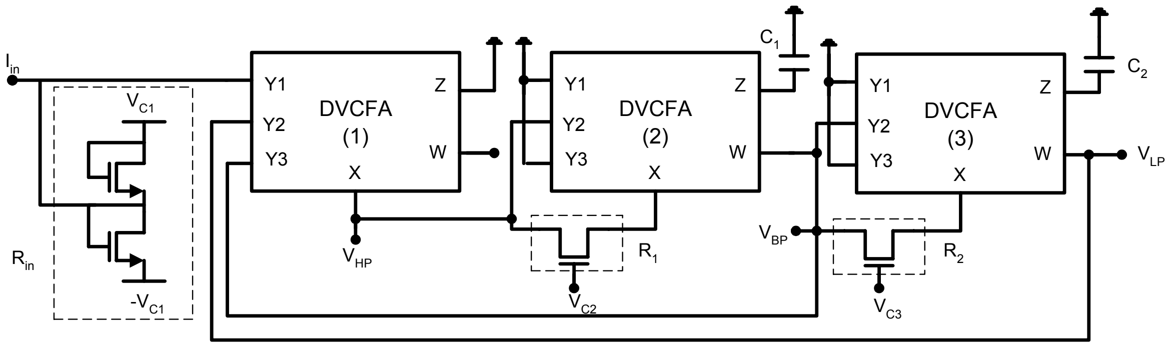

Figure 2: The proposed transimpedance type multifunction filter based on DVCFAs

The nodal analysis of the circuit shown in Figure 2 yields the following transimpedance transfer functions

$$\frac{V_{HP}}{I_{in}} = \frac{R_{in}s^2}{s^2 + \frac{2}{C_1R_1}s + \frac{4}{C_1C_2R_1R_2}} \quad (2a)$$

$$\frac{V_{BP}}{I_{in}} = -\frac{\frac{2R_{in}}{C_1R_1}s}{s^2 + \frac{2}{C_1R_1}s + \frac{4}{C_1C_2R_1R_2}} \quad (2b)$$

$$\frac{V_{LP}}{I_{in}} = \frac{\frac{4R_{in}}{C_1C_2R_1R_2}}{s^2 + \frac{2}{C_1R_1}s + \frac{4}{C_1C_2R_1R_2}} \quad (2c)$$

The central angular frequency ω_o and the quality factor Q of the filter can be expressed as

$$\omega_o = \sqrt{\frac{4}{R_1R_2C_1C_2}}, \quad Q = \sqrt{\frac{R_1C_1}{R_2C_2}} \quad (3)$$

It should be noted that ω_o and Q are orthogonally adjustable. In addition, the three basic filter functions (HP, BP and LP) are obtained simultaneously. It is worth noting that the resistors R_1 and R_2 are linear resistors and obtained by the MOS transistors with their drain current non-linearity cancelled by the DVCFA, since the MOS transistors are connected between Y_2 and X terminals of which have opposite voltages [19]. On the other hand, the resistor R_{in} is formed by two MOS transistors that act as a linear controllable resistor [20]. These MOS resistances can be adjusted electrically by their gate voltages, i.e., the filter can be electrically tuned.

The sensitivity analysis of the proposed circuit shows that

$$S_{R_1}^{\omega_o} = S_{C_1}^{Q} = -S_{R_2}^{Q} = -S_{C_2}^{Q} = \frac{1}{2},$$
$$S_{C_1}^{\omega_o} = S_{C_2}^{\omega_o} = S_{R_1}^{\omega_o} = S_{R_2}^{\omega_o} = -\frac{1}{2}$$

Thus, the entire sensitivities are low

III. SIMULATION RESULTS

The proposed multifunction filter circuit has been simulated using SPICE program to verify the given theoretical analysis. The DVCFAs have been simulated using the CMOS structure of Figure 3 [18]. The MOS transistors aspect ratios of the CMOS DVCFA are given in Table 1. The device model parameters used for the SPICE simulation are taken from MIETEC 0.5 µm CMOS process. The supply voltages have been selected as V_{DD}=–V_{SS}=2.5 V

Simulated gain (V_{out}/I_{in}) responses of the basic filter functions (HP, BP and LP) of the proposed multifunction filter circuit are given in Figure 4. For the simulation, the capacitance values of $C_2=C_1=20$ pF are chosen and the MOS resistors are biased to produce $R_{in}=1$ kΩ, $R_1=10$ kΩ and $R_2=20$ kΩ for a central frequency of $f_o\approx1.25$ MHz and a quality factor of Q=0.707. From Figure 4 it can be realized that the theoretical and simulation results are in good agreement.

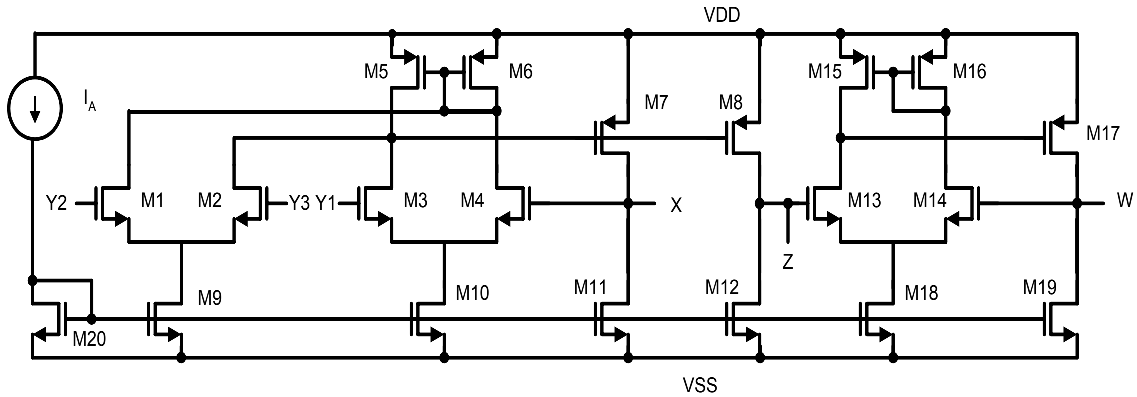

Figure 3: The CMOS structure of DVCFA [18]

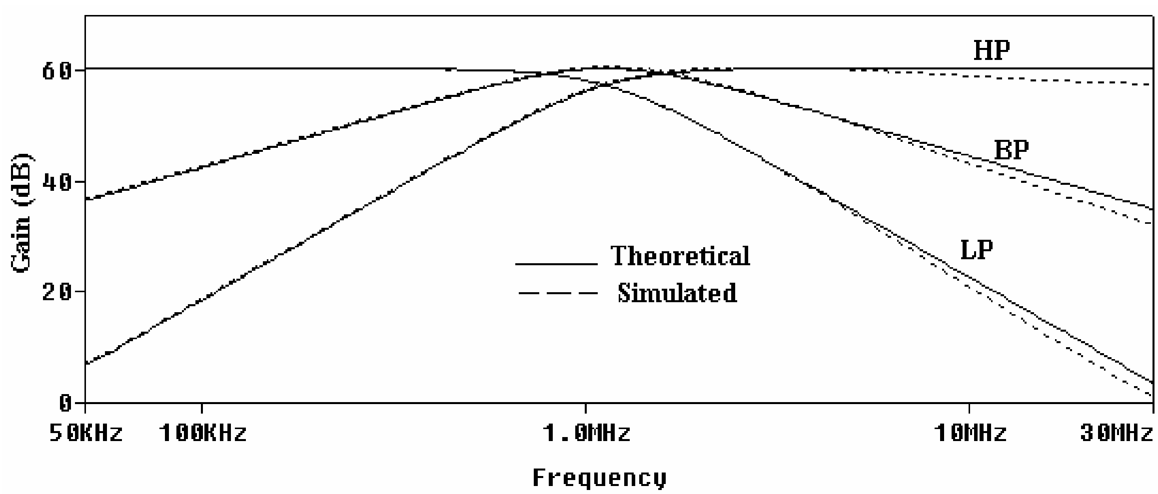

Figure 4: Simulated gain responses of the basic filter functions of the proposed multifunction filter

Table 1. Transistor aspect ratios of the DVCFA circuit given in Figure 3

TRANSISTOR	W (µm)	L (µm)
M1-M4	1.5	1
M5-M6	8	1
M7-M8	20	1
M9-M10	28	1
M11-M12	90	1
M13-M14	1.5	1
M15-M16	8	1
M17	20	1
M18-M20	90	1

IV. CONCLUSION

In this work, a transimpedance type multifunction filter circuit has been presented which can be electrically tuned. The filter employs three DVCFAs, two capacitors and three MOS resistors, which make it suitable for MOSFET-C Technology. Both the capacitors are grounded, which is important with respect to integrated circuit implementation. The filter provides the basic three filter functions (BP, HP and LP) simultaneously. The filter circuit has very low output impedance, of which other cells can be directly connected in cascade to which voltage signals are wanted to be applied. It should be noted that the proposed filter has low sensitivities.

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