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SINGLE FULLY DIFFERENTIAL CURRENT FEEDBACK OPERATIONAL AMPLIFIER (FDCFOA) BIQUADS WITH POSITIVE FEEDBACK TOPOLOGY

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ABSTRACT

New configuration for the design of biquad filters with positive feedback topology is presented. The configuration can synthesize low-pass, high-pass and band-pass filter functions according to the passive components used in circuits. The proposed configuration employs only one FDCFOA as active element and minimum number of passive elements, namely two capacitors and resistors. SPICE simulation results are given to confirm the validity of the analysis and to point out the high performance of the filters. The output of the filter exhibits high output impedance so that the synthesized filter can be cascaded without additional buffers.

Keywords: : *FDCFOA, biquad filters, high input and output impedances.*

1. INTRODUCTION

Biquad filters are of great interest because several cells of that kind can be connected in cascade to implement current conveyors (CCIIs) have received significant attention because of their high performance such as essentially extended band with and high values for the slow rate [1]. Therefore, several networks for realization of biquads based on CCII have been developed [2-10]. Some of them realize biquads with high input impedance, of which several cell can be direcly connected in cascade with no need to interpase active separate stages.

In this paper, configuration with positive feedback topology for the design of voltage-mode biquad filters are presented. They use only a recently proposed current feedback amplifier, named FDCFOA [11] as a single active element and minimum number of passive elements. The configuration achieves low-pass, high-pass and band-pass function according to the kind of passive componenets used. Proposed circiuts use grounded impedances and it is a known fact that grounded impedances are adventageous from integrated circuit implementations point of view. The naturel frequency ω_o and quality factor Q of the proposed filter are orthogonally adjustable.

2. THE PROPOSED CIRCUITS

The FDCFOA is basicly a fully differential device as shown in Figure 1. The Y_1 and Y_2 terminals are high impedance terminals while X_1 and X_2 terminals are low impedance ones. The differential input voltage V_{Y12} applied across Y_1 and Y_2 terminals is conveyed to differential voltage across the X_1 and X_2 termianls; i.e., (V_{X12} $=V_{Y12}$). The input currents applied to the

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X_1 and X_2 are conveyed to the Z_1 and Z_2 terminals are high ipmedance output nodes suitable for current outputs. The differential voltage developed across the Z_1 and Z_2 terminals are buffered by a unity gain fully differential voltage buffer to the output terminals O_1 and O_2, i.e., (V_{O12}= V_{Z12}).

An ideal FDCFOA, whose circuit symbol is shown in Figure.1, is a eight terminal network with terminal characteristics described by

$$\begin{bmatrix} V_{Y12} \\ I_{Z1} \\ I_{Z2} \\ V_{12} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_{X12} \\ I_{X1} \\ I_{X2} \\ V_{Z12} \end{bmatrix}$$
(1)

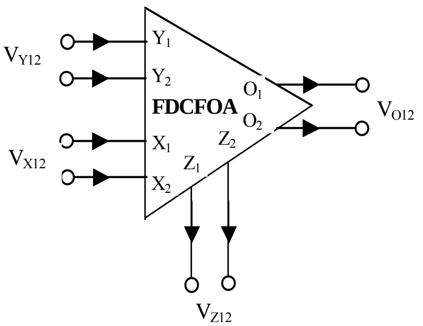

Fig. 1: *The Symbol of the FDCFOA*

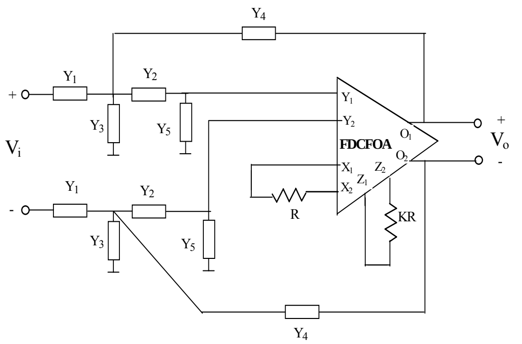

Fig. 2: *Proposed biqual filter configuration*

Considering circuit configuration shown in Figure.2, it is routine analysis yields the following transfer function

$$\frac{V_O}{V_I} = \frac{k y_1 y_2}{(y_2 + y_5)(y_1 + y_3 + y_4) + y_2 y_5 - k y_2 y_4} \quad (2)$$

If the admittance of the circuits are chosen as $y_1 = \frac{1}{R_1}$, $y_2 = \frac{1}{R_2}$, $y_3 = 0$, $y_4 = sC_1$ and $y_5 = sC_4$, (2) can be given as

$$\frac{V_O}{V_I} = \frac{K / R_1 R_2 C_1 C_2}{s^2 + \left[\frac{1}{R_1 C_1} + \frac{1}{R_2 C_2} + \frac{1-k}{R_2 C_2}\right] s + \frac{1}{R_1 R_2 C_1 C_2}} \quad (3)$$

From the above equation, for equal R and C design the ω_o, Q and DC gain H of the filter are given by;

$$\omega_o = \frac{1}{RC}, \; Q = \frac{1}{3-K}, \; \text{H=K} \quad (4)$$

If the admittance of the circuits of Figure.2 are chosen as $y_1 = sC_1$, $y_2 = sC_2$, $y_3 = 0$, $y_4 = \frac{1}{R_1}$ and $y_5 = \frac{1}{R_2}$, (2) can be given

$$\frac{V_O}{V_I} = \frac{k s^2}{s^2 + \left[\frac{1}{R_1 C_1} + \frac{1}{R_2 C_1} + \frac{1-k}{R_2 C_2}\right] s + \frac{1}{R_1 R_2 C_1 C_2}} \quad (5)$$

Then a high-pass filter can be realized and its naturel frequency ω_o and quality factor Q can be expresses as

$$\omega_o = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}, \; Q = \frac{1/\sqrt{R_1 R_2 C_1 C_2}}{\frac{1}{R_1 C_1} + \frac{1}{R_2 C_1} + \frac{1-k}{R_2 C_2}} \quad (6)$$

If the admittance of the circuits are chosen as $y_1 = \frac{1}{R_1}$, $y_2 = sC_2$, $y_3 = sC_1$, $y_4 = \frac{1}{R_2}$ and $y_5 = \frac{1}{R_3}$, (2) can be given

$$\frac{V_O}{V_I} = \frac{ks / R_1 C_1}{s^2 + \left[\frac{1}{R_1 C_1} + \frac{1}{R_3 C_2} + \frac{1}{R_3 C_1} + \frac{1-k}{R_2 C_1}\right] s + \frac{R_1 + R_2}{R_1 R_2 R_3 C_1 C_2}} \quad (7)$$

Then a band-pass filter can be realized and its naturel frequency ω_o and quality factor Q can be expresses as

$$\omega_o = \sqrt{\frac{R_1 + R_2}{R_1 R_2 R_3 C_1 C_2}}, \; Q = \frac{\sqrt{(R_1 + R_2)/R_1 R_2 R_3 C_1 C_2}}{\frac{1}{R_1 C_1} + \frac{1}{R_3 C_2} + \frac{1}{R_3 C_1} + \frac{1-k}{R_2 C_1}} \quad (8)$$

3. SIMULATION RESULTS

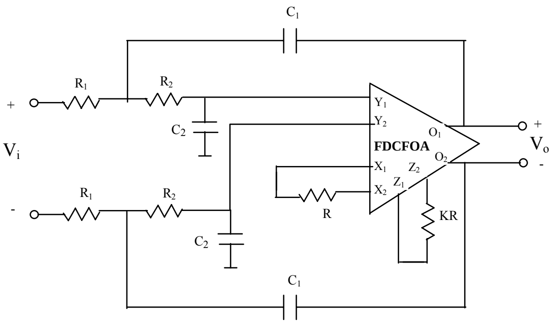

Fig. 3: *Second order fully differential low-pass filter based on a single FDCFOA*

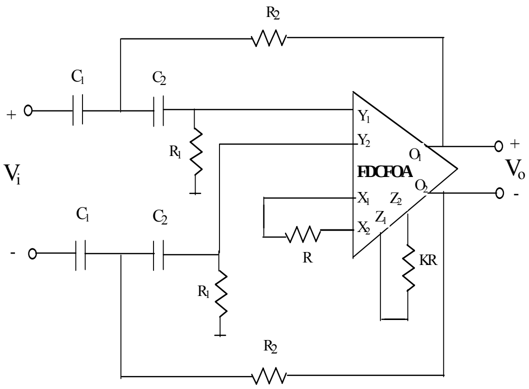

Fig. 4: *Second order fully differential high-pass filter based on a single FDCFOA*

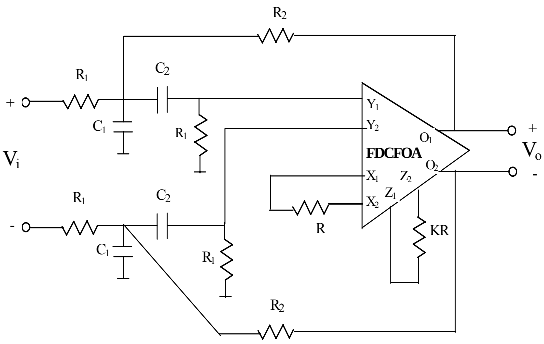

Fig. 5: *Second order fully differential band-pass filter based on a single FDCFOA*

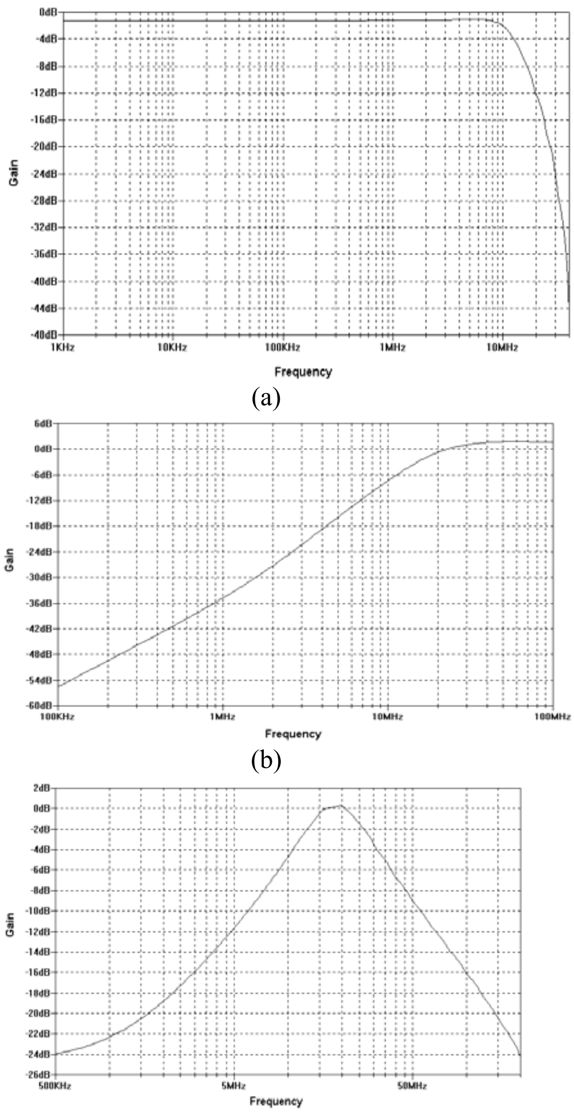

Fig.6: *Frequency responses of the proposed biquad filters of Figs. 3-5, a) low-pass, b) high-pass, c) band-pass*

In order to confirm the theoretical validity of the proposed filter configurations given in Figs. 3-5 they are simulated with SPICE simulation programs. Since there is no any commercial implementation of the FDCFOA, the SPICE simulations were performed using a CMOS realization of FDCFOA [12].Simulated frequency responses of the proposed filter circuits of Figs.3-5 are given in Fig.6.In simulations passive components were choosen as k=2, R=10kΩ, R_1=10kΩ and C=1pF, which results in 15.92 MHz center frequency. Figure.7. shows the simulated frequency response of a fourth order maximally flat low-pass filter consisting of two cascaded section of the filter shown in Figure.3. The fourth order filter provides 10dB gain and a bandwith of 16MHz to accomadate the wide band CDMA standart.For this purpose, passive components were chosen as R=10kΩ, R_1=10kΩ and C=1pF, which results in 15.92 MHz center frequency. Actually, the parasitic resistance and capacitances of CMOS FDCFOA, that is not mentioned in the limited space avaliable here, causes the deviations in the frequency and phase response of the filter from theoretical values. For either discrete or integrated implementation of the filter circuit, the designers should pay much attention to reduce the parasitics of FDCFOA.

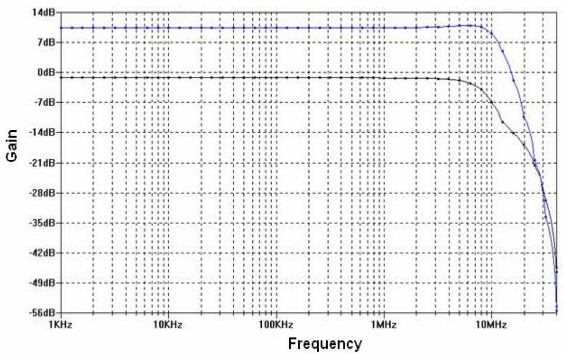

Fig. 7: *PSPICE simulation results frequency response of the fourth-order low-pass filter (Cascaded stages =▲, single stage = ■)*

4. CONCLUSION

In this work, new configuration for the design of voltage-mode biquad filters are presented. Configuration synthesizes low-pass, high-pass and band-pass filter functions according to the passive components used. The filter circuits employ only one FDCFOA, two capacitors and two resistors. Thus they employ minimum number of active and passive elements. The new configuration offer very high input impedance, which enables easy cascading. The simulation results demonstrate that the theoritical and simulation results are in good agreement. The proposed circutis are expected to be useful in analog filtering applications.

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