ISTANBUL UNIVERSITY –
JOURNAL OF ELECTRICAL & ELECTRONICS ENGINEERING

YEAR : 2006 (77 - 81)
VOLUME : 6
NUMBER : 1

# VOLTAGE MODE FIRST ORDER ALLPASS FILTER AND QUADRATURE OSCILLATOR EMPLOYING FULLY DIFFERENTIAL CURRENT FEEDBACK OPERATIONA

**Mahmut ÜN [1]** **Fırat KAÇAR [2]**

[1,2] Department of Electrical and Electronics Engineering , Istanbul University, Engineering Faculty
Istanbul, 34320, Turkey

[1]E-mail: unmahmut@istanbul.edu.tr [2]E-mail: fkacar@istanbul.edu.tr

## *ABSTRACT*

*A novel voltage-mode first-order all-pass filter configuration is proposed. The presented circuit uses single fully differential current feedback operational amplifier (FDCFOA), resistors and capacitors.The output of the filter exhibits fully differential buffer circuit so that the synthesized filter can be cascaded without additional buffers. Furthermore the proposed circuit is suitable for wide range, low voltage and low power applications. To demostrate the performance of the proposed filter the voltage mode quadrature oscillators are given as an application example. They are implemented through the proposed FDCFOA based first order allpass filter and integrator as a building blocks. The theoretical results are verified with SPICE simulations using CMOS realization of FDCFOA.*

***Keywords:*** *All-pass filter, fully differential current feedback operational amplifier, integrator, quadrature oscillator, analog integrated circuits*

## 1. INTRODUCTION

All-pass filter are one of the most important building block of many analog signal processing applications and therefore have recieved much attention. They are generally used for introducing a frequency dependent delay while keeping the amplitude of the input signal constant over the desired frequency range. Other type of the active circuits such as oscillators and high-Q band-pass filters are also realized by using all-pass filters [1-6]. The active devices that have been used for the realizations of first-order all-pass circuits include operational amplifiers (OP-AMP), second generation current conveyor (CCII), current feedback op-amps (CFOA), operational transconductance amplifier (OTA) and four terminal floating nullor (FTFN). Several voltage, transconductance and current mode first order all-pass filters are available in the literature [6-11]. Since the introduction of FDCFOA by Soliman, a few applications have appeared in the literature and CMOS realization of the FDCFOA is based on a novel class AB fully differential buffer circuits [12].The FDCFOA has the advantages of the single ended CFOA beside the advantages of the fully differential signal processing.

*Received Date :01.04.2004*
*Accepted Date: 09.12.2005*

In recent years, fully differential circuit configurations have been widely used in high frequency analog signal applications[13].As compared to their single ended counterparts; they have higher rejection capabilities to clock feed through, charge injection errors and power supply noises, larger output dynamic range, higher design flexibility, and reduced harmonic distortion.The main purpose of these paper is to propose a new application of FDCFOA as a voltage mode first and higher order all-pass filter. In this study, FDCFOA-based voltage-mode first order allpass filter configuration is proposed and also a quadrature oscillator is implemented to show the usefulness of the proposed configurationas an illustrating example.

## 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 $X_1$ and $X_2$ are conveyed to the $Z_1$ and $Z_2$ terminals are high impedance 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., ($V_{O12}=V_{Z12}$).

The part relations at an ideal FDCFOA, shown in Figure.1 can be given by

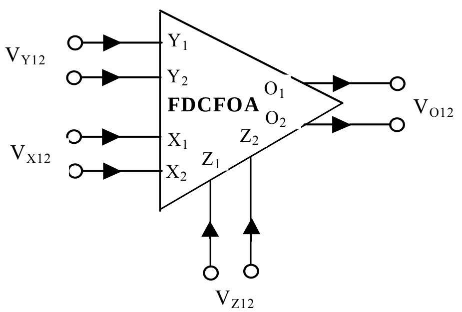


***Fig. 1: The Symbol of the FDCFOA***

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

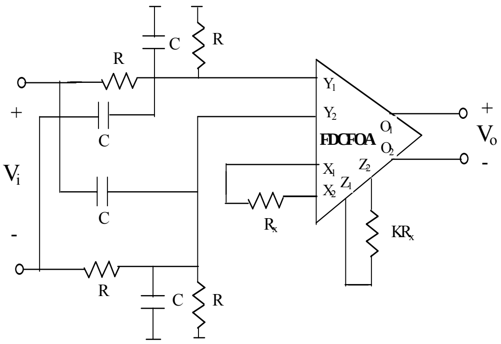


***Fig. 2: The proposed voltage mode first-order all-pass filter configuration***

The proposed configuration is shown in Figure.2. Routine analysis yields the voltage mode transfer function as follows

$$\frac{V_o}{V_i} = (-k)\,\frac{s - \dfrac{1}{R_1 C}}{s + \dfrac{1}{R_1 C}} \quad (2)$$

This transfer function allows the designer both inverting and noninverting types of first order voltage mode all-pass filters by exchanging *C* and *R* using only a single FDCFOA.Thus both inverting and noninverting types of first order voltage-mode allpass filters are realized using only a single FDCOA, resistors and capacitors.without imposing any passive element condition.

## 3. QUADRATURE OSCILLATOR AS AN ALLPASS FILTER APPLICATION

It is well-known fact that a sinusoidal oscillator can be realized using an allpass section and an integrator[13] as shown in Fig.3.

In this circuit, the proposed allpass filter and a voltage –mode integrator employing a FDCFOA with two matched resistors and capacitors are used.For providing a sinusoidal oscillation the loop gain of the circuit is set the unity at $s=jw$, i. e

$$\left[(-k)\frac{s-1/R_1C_1}{s+1/R_1C_1}\right]\left[-\frac{1}{sR_2C_2}\right]_{s=j\omega} = 1 \quad (3)$$

From Eq. (3) oscillation condition and frequency can be found respectively as

$$kR_1C_1 = R_2C_2 \quad (4)$$

$$\omega_0 = \sqrt{\frac{1}{R_1C_1R_2C_2}} \quad (5)$$

For simplicity, if we choose $R_1 = R_2 = R$ and $C_1 = C_2 = C$ , oscillation condition is satisfied and oscillation frequency becomes

$$\omega_0 = \frac{1}{RC} \quad (6)$$

## 4. SIMULATION RESULTS

To verify the theoritical study the first order all-pass filter was constructed and simulated with PSPICE program. For this purpose, passive components were chosen as R=10kΩ, $R_1$=1kΩ nd $C_1$=0.01nF, k=2 which results in 15.92 KHz center frequency. Since there is no any commerical implementation of the FDCFOA, the SPICE simulations were performed using a CMOS realization of FDCFOA [12]. Simulated magnitude and phase responses of the filter is given in Figure.4. 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.In order to test performance of the proposed allpass filter for the sinusoidal input, simulated output waveform of the proposed allpass filter is given in Fig.5. Quadrature oscillator employing the proposed allpass filter has also been simulated using PSPICE. In this simulation k=1, resistances and capacitances were taken as $R_1$=10 kΩ , $R_2$=100kΩ and $C_1$ =0.1nF, $C_2$ =0.01nF respectively which results in a 15.92 GHz oscillation frequency.The output waveforms of the oscillator are shown in Fig.6.

## 5. CONCLUSION

A voltage-mode first order allpass filter configuration is presented.The proposed circuit uses only a single FDCFOA, resistors and capacitors. The output of the filter exhibits fully differential buffer circuit so that the synthesized filter can be cascaded without additional buffers.The presented circuits are suitable for wide range, low voltage and low power applications. The proposed allpass filter is charecterized by the ability to achive high gain with low loss of bandwidth. The given circuits use a limited number of capacitors and resistors which simplifies integrated circuit implementation. As an application of the proposed filter, a new quadrature oscillator was realized. SPICE simulations were performed using CMOS realization of FDCFOA. SPICE simulation results of the filter performance are in good agreement with the predicted theory. It also provides an alternative solution to the realization of phase equalizer for analog signal processing applications.

## REFERENCES

[1] Schauman, R., Valkenburg E.,: Design of analog filters. Oxford University Press, New York, 2001.

[2] Donald, T. C., David, T.C., Jason, R. G.,: A high frequency integrable band-pass filter configuration, IEEE Transactions on Circuits and Systems, 44 (1997) 856-860.

[3] Cicekoglu, O., Kuntman, H., Berk, S.,: Single CCII+ based all-pass filters, Int. J. Of Electronics, 86 (1999), 947-959.

[4] Çam, U., Cicekoglu, O., Gülsoy, M., Kuntman, H.,: New voltage and current mode first-order all-pass filters using single FTFN, Frequenz, 7-8 (2000), 177-179.

[5] Higashimura M., Fukai, Y.,: Realization of all-pass and notch filters using a single current conveyor Int. J. Of Electronics, 65 (1988), 823-828.

[6] Toker, A., Ozoguz, S., Cicekoglu, O., Acar, C.,: Current mode all-pass filters using current differencing buffered amplifier and new high-Q band-pass filter configuration, IEEE Transaction on Circuits and Systems-II, 47 (2000), 949-954.

[7] Sudhanshu, S., Iqbal, A.K.,: Novel first order allpass section using single CCIII, Int. J. Electronics, 88 (2001), 773-778.

[8] Çam, U.,: A new transadmittance type first order allpass filter employing single third generation
current conveyor , Analog Integ. Circuits and Signal Proces., 43 (2005), 97-99.

[9] Wang, H. Y., Lee, C. T.,: Systematic synthesis R-L and C-D immitances using single CCIII, Electronic Letters, 88 (2000), 293-294.

[10] Minai ,S.,: A new high performance CMOS third generation current conveyor (CCIII)

and its application, Electrical Engineering, 85 (2003), 147-153.

[11] Toker, A., Cicekoglu, O., Özcan, S., Kuntman, H.,: High output impedance transadmittance type continious-time multifunction filter with minimum active elements International Journal of Electronics, 88 (2001), 1085-1091.

[12] Soliman A. M., Awad, I. A.,: Fully differential CMOS current feedback operational amplifier, Analog Integ. Circuits and Signal Processing, 43 (2005), 61-62.

[13] Alzaher H., Elwan H. O. And İsmail M.: A CMOS Fully balanced second-generation current conveyor, IEEE Trans on Circuits and Systems-II, 50(2003), 278-287.

[14] Haritantis, I.,: General method for designing RC harmonic oscillators, International Journal of Electronics, 58 (1985), 295-305.

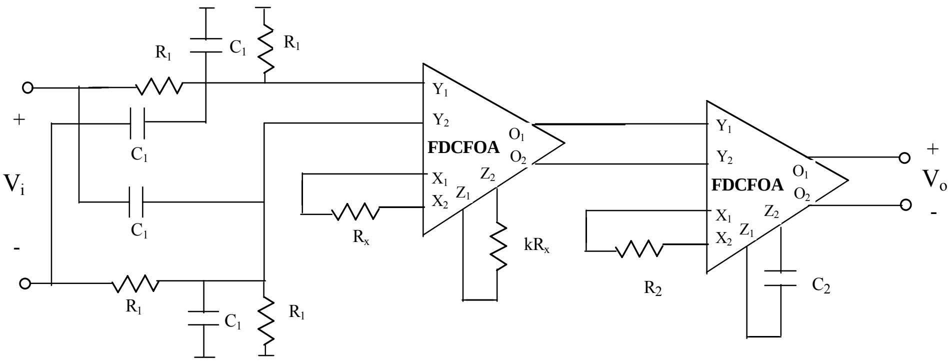


*Fig. 3: FDCFOA-based quadrature oscillator circuit*

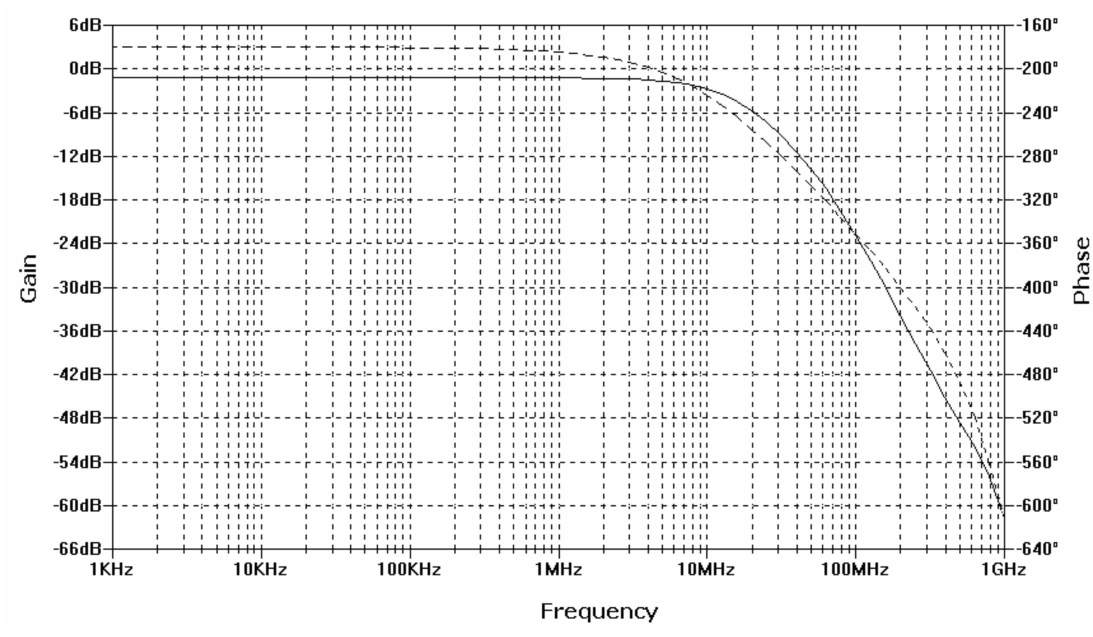


*Fig. 4: PSPICE simulation result(frequency response) of the proposed voltage-mode first-order allpass filter (Gain:—, Phase :---- )*

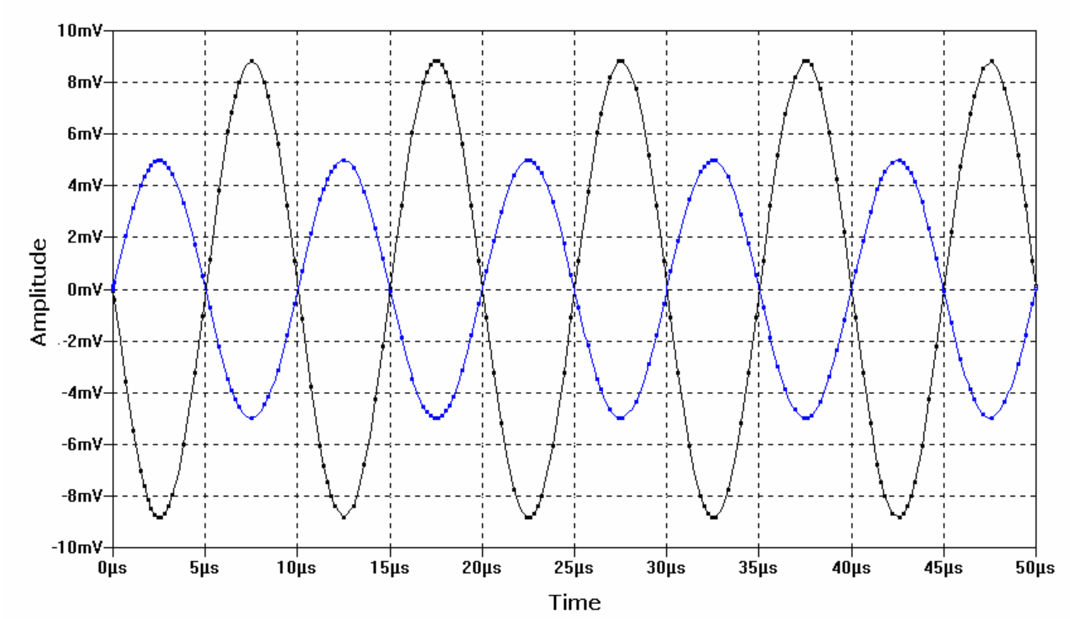


***Fig. 5: Simulated input-output waveforms of the proposed allpass filter (Input:■ Output:▲)***

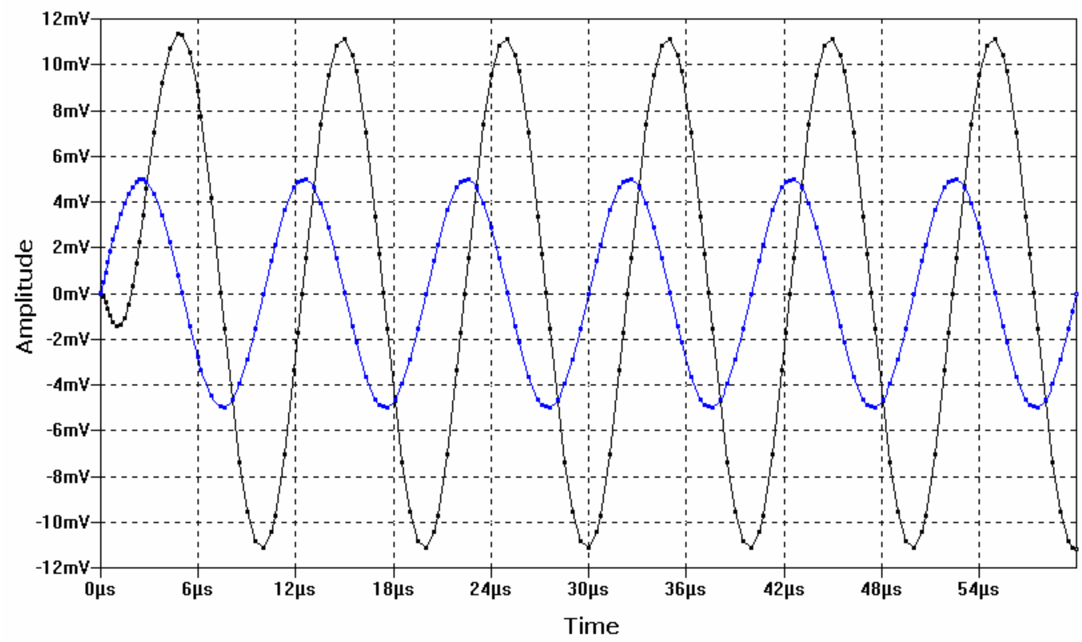


***Fig. 6: Simulated input-output waveforms of the quadrature (Input:■ Output:▲)***