A NOVEL CURRENT MODE UNIVERSAL ACTIVE-RC FILTER USING FDCCIIS

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ABSTRACT

A new current-mode universal active-RC filter is proposed. The proposed circuit is based on a new universal passive filter topology. Two Fully Differential Current Conveyors (FDCCII) are used to construct a universal active-RC filter from this passive filter. The FDCCII based proposed filter has only grounded resistances and capacitors as the passive elements. The circuit simultaneously provides the three basic filter characteristics, namely high-pass (HP), band-pass (BP) and low-pass (LP). SPICE simulation results are given to verify the theoretical analysis.

I. INTRODUCTION

A new active element, Fully Differential Current Conveyor has been presented in the literature [1]. Circuit symbol of FDCCII is shown in Fig. 1 and defining equations of the FDCCII is given in (1).

A number of circuit topologies have been proposed for the current mode universal filters using FDCCIIs [1,2]. Although these circuits have high output impedances, quality factor and pole frequency of these filters can not be controlled independently.

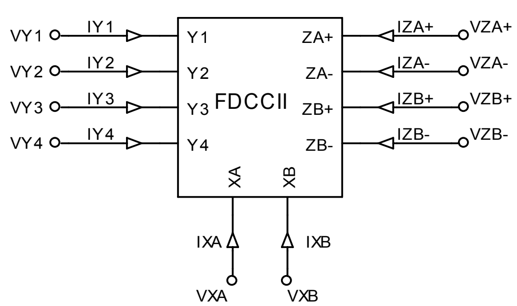

Figure 1: Circuit symbol of FDCCII

$$\begin{bmatrix} i_{Y1} \\ i_{Y2} \\ i_{Y3} \\ i_{Y4} \\ v_{XA} \\ v_{XB} \\ i_{ZA\pm} \\ i_{ZB\pm} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \pm 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \pm 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} v_{Y1} \\ v_{Y2} \\ v_{Y3} \\ v_{Y4} \\ i_{XA} \\ i_{XB} \\ v_{ZA\pm} \\ v_{ZB\pm} \end{bmatrix} \quad (1)$$

This paper presents a new current mode universal active-RC filter using two FDCCIIs, two grounded capacitors and three resistors. The proposed filter has high output impedance and its pole frequency and quality factor are independently adjustable.

II. CIRCUIT DESCRIPTION

A new current mode passive filter realization with RLC elements is shown in Fig. 2. It can be seen that from Fig. 2 a universal active-RC filter can easily be obtained simulating a lossless inductor.

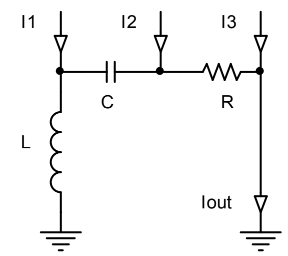

Figure 2: Universal passive filter

If I_{out} is the output current and $I_{1\text{-}3}$ are the input currents as shown in the Fig. 2, this filter can realize three filter functions (LP, BP, HP) simultaneously.

It can be seen from (2) that proposed passive filter represents a second order HP filter characteristic ($I_1=I_{in}$

and $I_2=I_3=0$), BP filter characteristic ($I3=-I2=I_{in}$ and $I_1=0$) and LP filter characteristic ($I_2=-I_1=I_{in}$ and $I_3=0$).

$$I_{out} = \frac{s^2(I_1+I_2+I_3)+\frac{R}{L}s(I_3)+\frac{1}{LC}(I_2+I_3)}{s^2+\frac{R}{L}s+\frac{1}{LC}} \quad (2)$$

At this point, some input currents are defined as the difference of two terminal currents. So that the LP and the BP filters are not defined as single input. Another problem is to realize floating serial RC circuit. It should be noted that it is possible to obtain an equivalent floating serial RC circuit by using a FDCCII and a grounded resistor and capacitor.

A Sedra-Smith gyrator based grounded lossless inductor simulation is given in Fig. 3 [3]. A floating serial RC equivalent circuit can be simulated by using FDCCII and grounded RC elements as shown in Fig. 4.

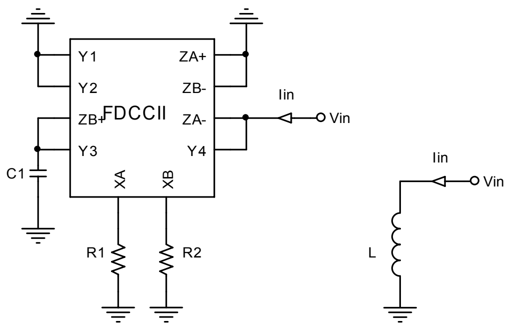

Figure 3: Grounded lossless inductor simulation [3]

$$\frac{V_{in}}{I_{in}} = R_1R_2C_1s\,, \quad L = R_1R_2C_1 \quad (3)$$

The RLC passive universal filter in Fig. 2 can actively be implemented as shown in Fig. 5.

The proposed filter given in Fig. 5 employs two FDCCIIs, two capacitors and three resistors.

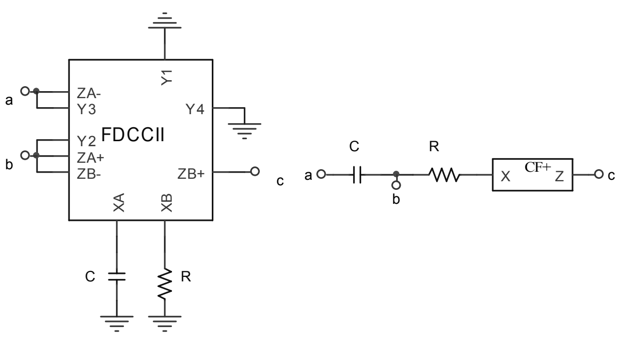

Figure 4: Floating serial-RC equivalent circuit

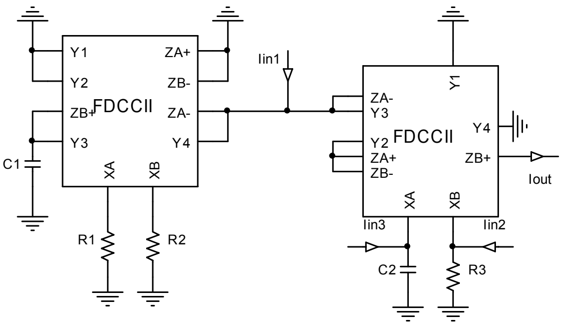

Figure 5: Proposed universal active-RC filter

The transfer functions of this circuit are given as the following:

$$Iout = \frac{(s^2)Iin_1 - \left(\frac{R_3}{R_1R_2C_1}s\right)Iin_2 - \left(\frac{1}{R_1C_1R_2C_2}\right)Iin_3}{s^2+\frac{R_3}{R_1R_2C_1}s+\frac{1}{R_1C_1R_2C_2}} \quad (4)$$

Although some passive components of the passive universal filter in Fig. 2 are not grounded, it should be noted that, in the proposed universal active-RC filter in Fig. 5, three inputs realize three filter characteristics simultaneously and all passive components are grounded.

The natural frequency ω_p and quality factor Q_p of the proposed filter are given by (5).

$$\omega_p = \sqrt{\frac{1}{R_1C_1R_2C_2}}\,, \quad Q_p = \frac{1}{R_3}\sqrt{\frac{R_1R_2C_1}{C_2}} \quad (5)$$

As it is seen from (5), ω_p and Q_p are independently adjustable by the value of R_3.

The passive sensitivities of the parameters ω_p and Q_p can be expressed as given in (6,7).

$$S_{R1}^{wp} = S_{R2}^{wp} = S_{C1}^{wp} = S_{C2}^{wp} = -\frac{1}{2}\,, \; S_{R3}^{wp} = 0 \quad (6)$$

$$S_{R3}^{Qp} = -1\,, \; S_{C2}^{Qp} = -\frac{1}{2}\,, \; S_{R1}^{Qp} = S_{R2}^{Qp} = S_{C1}^{Qp} = \frac{1}{2} \quad (7)$$

From the above calculations, it can be seen that all sensitivities are equal or smaller than unity.

III. SIMULATION RESULTS

To verify the theoretical predictions, the proposed universal active-RC filter was simulated in SPICE program. We implemented FDCCIIs using the CMOS realization of FDCCII given in Fig. 6.

SPICE model parameters of transistors are extracted from 0.35μm MOSIS process. The dimensions of the MOSFETs of the FDCCII given in [1] were made smaller and given in Table 1. DC biasing levels are VDD=-VSS=1.3V, Vbp=Vbn=0, IB=25µA and ISB=20µA [5]. Passive element values of the proposed filter are chosen $R_1=R_2=R_3=2.25k\Omega$, $C_1=200pF$, $C_2=400pF$ to realize a butterworth-type filter response with a natural frequency of $f_0=250$ kHz. As shown in Fig. 7-9, the simulation results are agree well with the theoretical analysis.

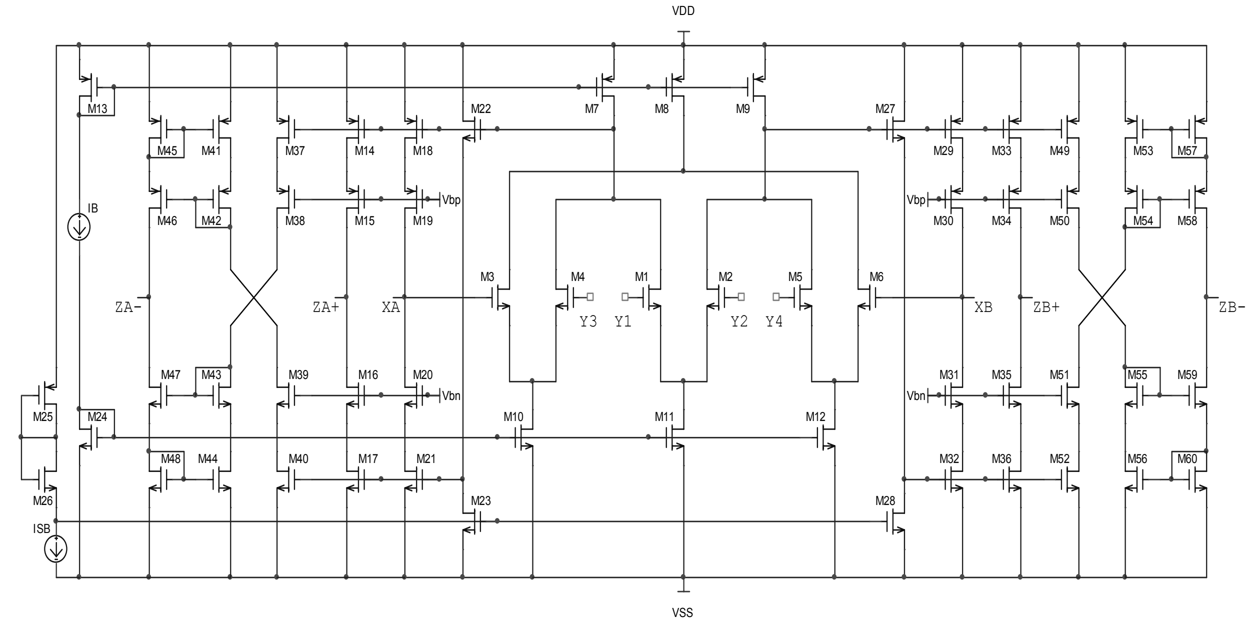

Figure 6: A CMOS realization of FDCCII [4]

Table 1: Dimensions of the MOSFETs used in implementation of the FDCCII

M1-M6	8.75µ/0.7µ
M7, M8, M9, M13	70µ/0.7µ
M10, M11, M12, M24	17.5µ/0.7µ
M14, M15, M18, M19, M25, M29, M30, M33, M34, M37, M38, M41, M42, M45, M46, M49, M50, M53, M54, M57, M58	35µ/0.35µ
M16, M17, M20, M21, M26, M31, M32, M35, M36, M39, M40, M43, M44, M47, M48, M51, M52, M55, M56, M59, M60	8.75µ/0.35µ
M22, M23, M27, M28,	0.7µ/0.7µ

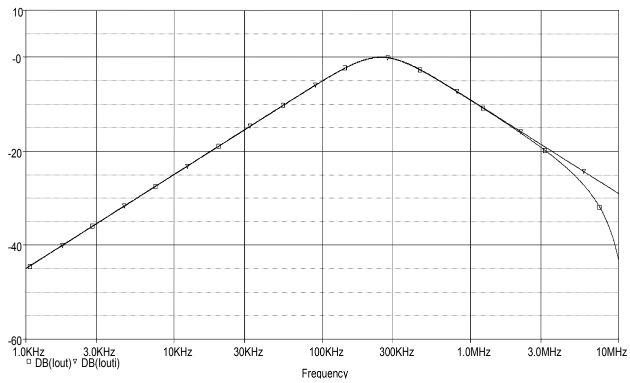

Figure 8: BP response of the proposed filter

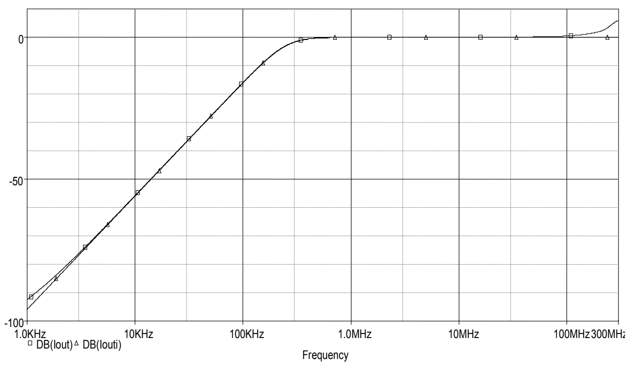

Figure 7: HP response of the proposed filter

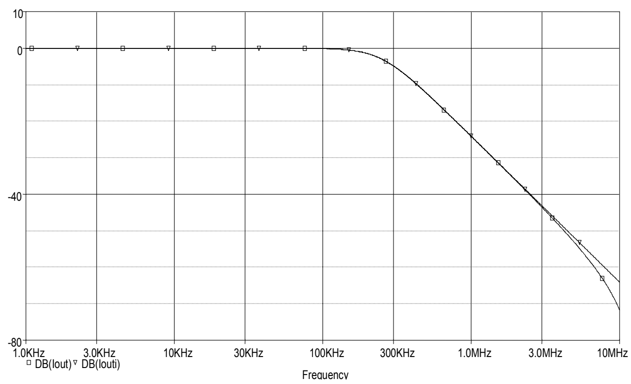

Figure 9: LP response of the proposed filter

IV. CONCLUSION

A new current-mode universal active-RC filter has been proposed using FDCCIIs. A new current mode universal passive filter has also been given. This passive universal filter has a lossless inductor and a serial RC circuit. This passive filter has been actively implemented using two FDCCIIs and five passive elements. One of the FDCCIIs is used to simulate a lossless inductor and the other is used to construct a serial RC circuit. The proposed filter has high output impedance and independently adjustable pole frequency and quality factor. All passive components used in the proposed filter are grounded. The filter has low sensitivities to the passive components. Simulation results are agree well with the theoretical results.

REFERENCES

1- El-Adawy, A. A., Soliman, A. M. and Elwan, H. O., "A novel fully differential current conveyor and applications for analog VLSI", IEEE Trans. Circuits System II, Analog Digit. Signal Proc., 47, 306-313, 2000.

2- Chang, C. M., Al-Hashimi, B. M., Wang, C. L. and Hung., C. W., "Single fully differential current conveyor biquad filters", IEE Proc. Circuits Devices Syst., 150,394-398, 2003.

3- Öner, L. and Yüce, E. and Çiçekoğlu O., "New inductor simulators employing single FDCCII", IASTED International Conference Circuits, Signals, Systems, 2004.

4- Horng, J. W., Hou, C. L., Chang, C. M., Chou, H. P., Lin, C. T. and Wen, Y. H., "Quadrature Oscillators with Grounded Capacitors and Resistors Using FDCCIIs", ETRI Journal, 28, 486-494., 2006.

5- Gür, F, "Universal active-RC filter design using fully differential current conveyor (FDCCII)" Master thesis, Istanbul Technical University, Institute of Science and Technology, 2007.