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An All Pass Tunable Universal Filter Based on Second Generation Dual Output Current Controlled Conveyor (DOCCCII)

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***Abstract* – Current mode VLSI devices such as current conveyors have established their identity as the most demanding devices in the area of signal processing due to their high bandwidth, greater linearity, larger dynamic range, low power consumption, simple circuitry and occupy less chip area. CCCIIs are widely used as basic active building blocks to realize various current-mode active filters. The universal filter is among the most popular analog filters as it can provide several standard functions like low pass, high pass, band pass, and band reject and all pass In this paper we have proposed a Tunable Universal Filter that employs the use of only Current Controlled Conveyors and Capacitors. Various simulations have been carried out to obtain the desired results. The outcomes show that the proposed circuit works well as an All Pass Tunable Universal filter.**

***Keywords* – Current Controlled Conveyor, Tunable Universal Filter (TUF), DOCCCII.**

I. INTRODUCTION

The second generation Current Controlled Conveyors (CCCIIs) is widely used as basic active building blocks to realize various current-mode active filters. The universal filter is among the most popular analog filters as it can provide several standard functions like low pass, high pass, band pass, and band reject and all pass. In this section, a current mode universal filter has been implemented with single input and three different outputs for low, high and band pass filters. Implementation of Universal filter[2,3] is shown in Fig.1. using only two DOCCCII[7] and two capacitors, as the dual-output current conveyors is useful in the derivation of current-mode single input and three output filters using a reduced number of active components. Previously, many realizations of current mode biquadratic filters using CCCIIs have been reported.

In this paper dual output current controlled current conveyor (DOCCCII) is simulated by using 350nm CMOS technology and its application[4] as a Universal Filter is simulated which is beneficial in the field of analog signal processing like high frequency tunable universal filter.

II. BACKGROUND

Current conveyors and current mode circuits have reasonably established their identity as an important circuit design element. The second generation dual output current controlled conveyor (DOCCCII) has proven the most promising technology over the CCII because of its advantage of electronic tunability therefore it is most frequently used in the world of current mode to design different analog circuits. The dual-output current conveyors is useful in the derivation of current-mode single input and three output filters using a reduced number of active components. The DOCCCII can also be used to design a Tunable filter [7]. The proposed filter realization is shown in Figure 1 where two DOCCCII elements are considered having ideal terminal properties. This circuit enjoys the circuit simplicity, as it utilizes only two DOCCCII or dual output current controlled conveyor and just two capacitors.

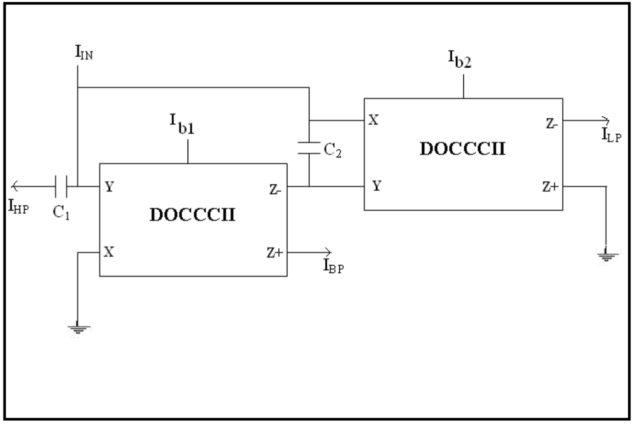

Fig.1. Block diagram of Tunable Universal Filter

The analysis of the filter circuit is given below:

After solving the equations corresponding to nodes and loops of the circuit we get the following relations.

$$\frac{I_{HP}}{I_{IN}} = -\frac{s^2}{D(s)} \qquad \text{... (2.1)}$$

$$\frac{I_{LP}}{I_{IN}} = \frac{-\frac{1}{R_{x1}R_{x2}C_1C_2}}{D(s)} \qquad \text{... (2.2)}$$

$$\frac{I_{BP}}{I_{IN}} = \frac{\frac{s}{R_{x1}C_1}}{D(s)} \qquad \text{... (2.3)}$$

Where

$$D(s) = \left(s^2 + \frac{s}{R_{x1}C_1} + \frac{1}{R_{x1}R_{x2}C_1C_2}\right)$$

Moreover, the band reject i.e. notch filter response of the proposed filter can be obtained by connecting I_{HP} and I_{LP} together as follows:

$$\frac{I_N}{I_{IN}} = \frac{I_{HP} + I_{LP}}{I_{IN}} = -\frac{s^2 + \frac{1}{R_{x1}R_{x2}C_1C_2}}{D(s)} \qquad \text{... (2.4)}$$

Similarly by connecting together I_{HP}, I_{LP} and I_{BP}, an All Pass filter response is obtained,

$$\frac{I_{AP}}{I_{IN}} = -\frac{I_{HP} + I_{LP} + I_{BP}}{I_{IN}}$$

$$= -\frac{s^2 - \frac{s}{R_{x1}C_1} + \frac{1}{R_{x1}R_{x2}C_1C_2}}{D(s)} \qquad \ldots(2.5)$$

The natural frequency ω_0, the bandwidth ω_0/Q and the quality factor Q are,

$$\omega_0 = \sqrt{\left(\frac{1}{R_{x1}R_{x2}C_1C_2}\right)} \qquad \ldots(2.6)$$

$$\frac{\omega_0}{Q} = \frac{1}{R_{x1}C_1} \qquad \ldots(2.7)$$

$$Q = \sqrt{\frac{R_{x1}C_1}{R_{x2}C_2}} \qquad \ldots(2.8)$$

The above equations clearly indicate that ω_0 and ω_0/Q can be adjusted by the bias currents I_{b1} and I_{b2} of the respective DOCCCII. Transmission of Universal Filter is given by-

$$T(s) = \frac{a_2 s^2 + a_1 s + a_o}{s^2 + \left(\frac{\omega_o}{Q}\right) s + \omega_o^2} \qquad \ldots(2.9)$$

And in our implementation
$a_2 = 1$, $a_1 = 1/R_{x1}C_1$ and $a_o = \omega_o^2$
For low pass filter; dc gain= $a_o/\omega_o^2 = 1$
For high pass filter; high frequency gain = $a_2 = 1$
For band pass; gain at $\omega_o = a_1 Q/\omega_o = 1$
For notch filter; dc gain=a_2
For all pass filter; flat gain = $a_2 = 1$

III. PROPOSED DESIGN

Tunable Universal Filter for $\left(Q = \frac{1}{\sqrt{2}}\right)$

The following values of capacitors and bias currents have been used for the implementation of this Universal Filter:
$C_1 = 15pF$, $C_2 = 30pF$;
$I_{B1} = 80\mu A$ i.e. $R_{X1} = 565.37\ \Omega$;
$I_{B2} = 80\mu A$ i.e. $R_{X2} = 565.37\Omega$.

Table 1: Theoretical values of the Proposed Filter

Parameters	LP filter	HP filter	BP filter	Notch filter	AP filter
Gain	1	1	1	1	1
Cutoff Frequency	13.28MHz	13.28 MHz	13.28MHz (Peak)	13.28MHz (peak)	-
Band Width	**13.28MHz**	**(13.28-∞) MHz**	**18.78MHz**	**18.97MHz**	-

Cut off frequency ω_o=83.39MHz
i.e. f_o = 13.28MHz
Quality factor Q=0.70 & Band Width
ω_o/Q= 119.13MHz.

IV. SIMULATION RESULTS

For realizations, of the above Universal Filter, CMOS design of DOCCCII is adopted, and the filter of Fig.1 is simulated on PSPICE OrCAD v9.0. The simulation results of the filter are presented in Fig.2 and Fig.3. Figure 2 shows frequency responses for low, high & band pass filter and figure 3 shows the Frequency Response for All Pass and Notch Filter.

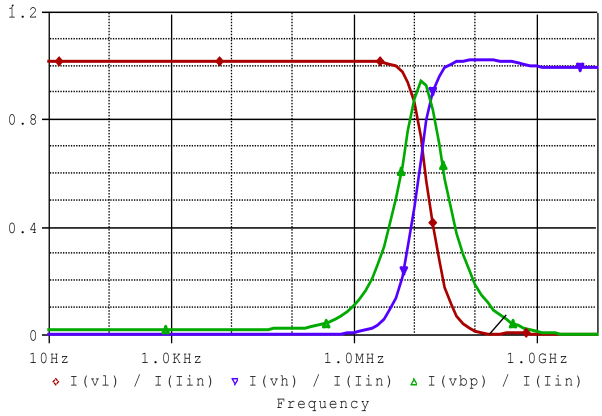

Fig.2. Frequency response of LP, HP and BP Filters

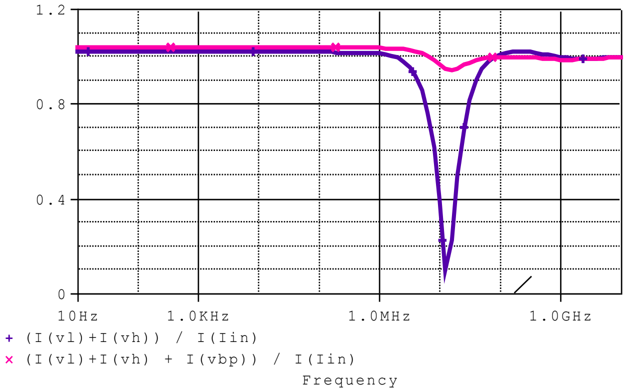

Fig.3. Frequency response of All Pass and Notch Filter

The simulation results obtained above by successive simulations is tabulated in Table 2 and is compared with the theoretical values of Table 1.

Table 2: Practical values of the Proposed Filter after Simulation

Parameters	LP filter	HP filter	BP filter	Notch filter	AP filter
Gain	**1.01**	**1.01**	**0.94**	**1.01**	**1.01**
Cutoff Frequency	13.12 MHz	13.87MHz	13.07MHz (Peak)	12.28MHz (peak)	-
Band Width	**13.12 MHz**	**(13.87-∞) MHz**	**20.31MHz**	**19.14MHz**	-

Cut-off frequency ω_O=82.08MHz
i.e. f_O = 13.07MHz
Band Width ω_O/Q = 118.95MHz.
Total power dissipation in universal filter is 6.29mW.

V. CONCLUSION

The simulation results show that the universal filter designed in this paper is of tunable nature since the cutoff frequency of the filter depends on the variation in the device bias current(I_b). Hence, the designed band pass filter becomes more selective in reference to the band of frequencies and it can also be seen that overshoot occurs as the value of Q factor is increased.

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