Current Conveyor Based Multifunction Filter

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Abstract—The paper presents a current conveyor based multifunction filter. The proposed circuit can be realized as low pass, high pass, band pass and elliptical notch filter. The circuit employs two balanced output current conveyors, four resistors and two grounded capacitors, ideal for integration. It has only one output terminal and the number of input terminals may be used. Further, there is no requirement for component matching in the circuit. The parameter resonance frequency ($\omega_0$) and bandwidth ($\omega_0/Q$) enjoy orthogonal tuning. The complementary metal oxide semiconductor (CMOS) realization of the current conveyor is given for the simulation of the proposed circuit. A HSPICE simulation of circuit is also studied for the verification of theoretical results. The non-ideal analysis of CCII is also studied. (Abstract)

Keywords—Active filters, Current Conveyor, Voltage-mode.

I. INTRODUCTION (HEADING 1)

Active filters are widely used in the signal processing and instrumentation area. The well known advantage of current mode operation, such as better linearity, simple circuitry, low power consumption and greater bandwidth becomes more attractive as compared to voltage-mode counterpart with introduction of Current Conveyor II (CCII). The application and advantages in the realization of various active filters using current conveyors has received considerable attention [1]-[5]. Some voltage mode multifunction filter using current conveyors have also been proposed. In 1995 Soliman [1] proposed Kerwin-Huelsman-Newcomb (KHN) biquad with single input and three outputs, which realizes low-pass, band-pass and high-pass filter. The circuit employs five current conveyor (CCII), two capacitors and six resistors. In 1997 Higahimura et al. [2] proposed a universal voltage-mode filter that can realize low-pass, high-pass, band-pass, all-pass and notch filter using seven current conveyors, two capacitors and eight resistors. Ozoguz et al. [3] realized high-pass, low-pass and band-pass filter using three positive type current conveyor and five passive components. In 1999 Chang and Lee [4] proposed voltage mode low-pass, band-pass and high-pass filter with single input and three outputs employing only current conveyors, two grounded capacitors and three resistors. Toker et al. [5] realized high output impedance transadmittance type continuous time multifunction filter (low-pass, high-pass and band-pass) employing three positive type current conveyor and five passive components. The circuit proposes high output impedance.

In this paper a circuit employing two balanced output current conveyors, four resistors and two grounded capacitors is proposed. This circuit has one output terminal and four input terminals. All the basic filters (low pass, high pass, band pass and notch filter) may be realized by selecting appropriate input terminals of the circuit.

The following section presents circuit description of the balanced output current conveyor. The sensitivity analysis, nonideal analysis of balanced output current conveyors, simulation results and conclusion are discussed in the subsequent sections.

II. CIRCUIT DESCRIPTION

The balanced output current conveyor is shown in fig 1 with its symbol, characterized by the port relations as given by “(1)”

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Figure 1. Symbol of balanced output current Conveyor
\[
\begin{bmatrix}
V_x \\
I_y \\
I_{z+} \\
I_{z-}
\end{bmatrix} =
\begin{bmatrix}
0 & B & 0 & 0 \\
0 & 0 & 0 & 0 \\
K & 0 & 0 & 0 \\
-K & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
I_x \\
V_y \\
V_{z+} \\
V_{z-}
\end{bmatrix}
\] (1)

The values of B and K are frequency dependent and ideally B=1 and K=1.

The proposed circuit shown in fig 2 employs only two balanced output current conveyor, four resistor and two capacitors. The grounded capacitors are particularly very attractive for the integrated circuit implementation.

\[
V_{out} = \frac{s^2C_2C_5}{D(s)} \left[ \frac{R_3R_6}{s^2C_2C_5} V_1 + \frac{R_1R_4R_6}{s^2C_2C_5} V_2 + \frac{R_1R_3}{s^2C_2C_5} V_3 + \frac{R_1R_3}{s^2C_2C_5} V_4 \right]
\] (2)

Where

\[
D(s) = s^3C_2C_5R_1R_3R_4R_6 + sC_2R_1R_4R_6 + (R_1R_3 + R_3R_6)
\] (3)

Thus by using “(2)” we can realize low-pass, band-pass, high-pass and notch filter responses at the single output terminal by applying proper inputs at different node as shown in table1.

The denominators for the all filter responses are same. The filtering parameter \(\omega_0\), \(\omega_0/Q\) and Q are given by

\[
\omega_0 = \sqrt{\frac{R_1 + R_6}{R_1R_4R_6C_2C_5}}
\] (4)

\[
\frac{\omega_0}{Q} = \frac{1}{R_2C_3}
\] (5)

| Filter/Input | \(V_1\) | \(V_2\) | \(V_3\) | \(V_4\) |
|-------------|--------|--------|--------|--------|
| Low-pass    | 1      | 0      | 0      | 1      |
| High-pass   | 0      | 1      | 0      | 0      |
| Band-pass   | 0      | 0      | 1      | 0      |
| Notch      | 1      | 1      | 0      | 1      |

\[
Q = R_1 \sqrt{\frac{C_3(R_1 + R_6)}{R_1R_4R_6C_5}}
\] (6)

It can be seen from a perusal of “(4)” - “(6)” that both the center frequency and quality factor are independent. An inspection of “(4)” and “(5)” shows that \(\omega_0\) and \(\omega_0/Q\) can be orthogonally tuned through \(R_6\) and /or \(C_5\) and \(R_3\) and /or \(C_2\) in that order.

III. SENSITIVITY ANALYSIS

The sensitivity analysis of the proposed circuit is presented in terms of the sensitivity of \(\omega_0\) and Q with respect to the variation in the passive components as follows:

\[
S_{C_2,C_5,R_4}^{\omega_0} = -\frac{1}{2}
\] (7)

\[
S_{R_1}^{\omega_0} = -\frac{R_6}{2(R_1 + R_6)}
\] (8)

\[
S_{R_6}^{\omega_0} = -\frac{R_1}{2(R_1 + R_6)}
\] (9)

\[
S_{R_3}^Q = 1
\] (10)

\[
S_{C_2}^Q = \frac{1}{2}
\] (11)

\[
S_{R_4,C_5}^Q = -\frac{1}{2}
\] (12)
\[ S_{R_1}^{Q} = -\frac{R_{e1}}{2(R_1 + R_e)} \quad (13) \]
\[ S_{R_e}^{Q} = -\frac{R_1}{2(R_1 + R_e)} \quad (14) \]

As per these expressions, both the \( \omega_0 \) and \( Q \) sensitivities are less than \( \pm \frac{1}{2} \) with a maximum value of \( S_{R_1}^{Q} = 1 \).

**IV. NONIDEAL ANALYSIS**

Practically \( B \) and \( K \) are frequency dependent with dominant poles and therefore intended to nonideal. The non ideal behavior of the output \( V_{out} \) may be expressed by “(15)”.

\[
V_{out} = \frac{s^2C_2C_4}{D(s)} \left[ \frac{R_2^2}{s^2C_2C_5} V_1 + \frac{K_1K_2B_1B_2R_1R_4R_5R_6V_2}{sC_2} + \frac{R_2R_3}{s^2C_2C_5} V_4 \right]
\]

Where

\[
D(s) = K_1K_2B_1B_2(s^2C_2C_5V_1R_3R_4R_5R_6 + sC_2V_1R_4R_5R_6 + R_4R_5 + R_3R_5)
\]

\[
\omega_0 = \sqrt{\frac{R_1 + R_e}{K_1K_2B_1B_2R_1R_4R_5C_2C_5}}
\]

\[
\frac{\omega_0}{Q} = \frac{1}{C_2R_3}
\]

\[
Q = R_3\sqrt{\frac{C_2(R_1 + R_e)}{K_1K_2B_1B_2R_1R_4R_5C_2C_5}}
\]

It can be observed that the effect of non ideality behavior on cutoff frequency (\( \omega_0 \)) and \( Q \) will be negligible and bandwidth will not be affected. The sensitivity analysis of cutoff frequency and the quality factor with respect to \( K_1 \), \( K_2 \), \( B_1 \) and \( B_2 \) are as follows:

\[
S_{\omega_0}^{\omega_0} = -\frac{1}{2}
\]

\[
S_{\omega_0,B_1,K_1,K_2}^{Q} = -\frac{1}{2}
\]

The \( \omega_0 \) and \( Q \) sensitivities with respect to passive components are same in case of ideal balanced output current conveyor.

**V. SIMULATION RESULT**

The HSPICE simulation with 0.5µm CMOS transistor model provided by MOSIS has been carried out for the realization of balanced output current conveyor as shown in fig (3). Table 2 list the dimension on NMOS and PMOS transistor of this circuit. Figure 4 displays the simulation result for the proposed filter. The circuit is designed for \( \omega_0 = 14.14 \) KHz and \( Q=2 \) by considering \( R_1 = R_4 = R_6 = 10\,\text{K} \,\Omega \), \( C_2 = C_5 = 10\,\text{nF} \) and \( R_3 = 14\,\text{K} \,\Omega \). The theoretical results have been verified to match with simulation result.
VI. CONCLUSION

The circuit proposed by Hong et al. and Chang et al. uses more active and passive components. Whereas the circuit proposed in this paper generates low-pass, high-pass, band-pass and notch filter using two balanced output current conveyors, four resistors and two capacitors. The circuit provides more number of filter realizations at the single output terminal using two current conveyors. In addition of this proposed circuit does not have any matching constraint/cancellation condition. The circuit employs grounded capacitor, suitable for IC fabrication. The circuit enjoys the orthogonality between the cutoff frequency and the bandwidth. It has low sensitivities figure of both active and passive components.

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