

A Filter with Three Voltage-inputs and One Voltage-output and One Current-output Using Current Conveyors

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Abstract

A new biquadratic filter with three voltage-inputs and one voltage-output and one current-output is presented. The filter employs two types of current conveyors, grounded resistors and grounded capacitors to realize the lowpass, highpass and bandpass responses by selecting different input signals. The proposed circuit has high input impedance, independent adjustments of angular frequency ω_0 and quality factor Q using capacitors and resistors, in addition to low active and passive sensitivities. Hspice simulation results are given to demonstrate the new proposed biquadratic filter.

Key Words: Current Conveyors, Biquadratic Filter, DDCC (Differential Difference Current Conveyor), CCII (Second-generation Current Conveyor).

1. Introduction

Because of the higher bandwidth performance, the higher dynamic range and linearity existing in the current conveyors, to design the current-mode circuits, such as filters and oscillators, become more popular in the past years than to the voltage-mode circuits. In particular, the second-generation current conveyor (CCII) is very suitable for filter design, many universal biquadratic filters [1–4] employing CCIIs are also presented. In this paper, a biquadratic filter using differential difference current conveyors (DDCCs) and CCIIs to implement lowpass, highpass and bandpass signals is proposed.

CCII is a popular building block which can be used in filtering construction. Its symbol is shown in Figure 1. Port Y has high input impedance and is suitable for applying a voltage signal input, port Z has high output impedance and is suitable for obtaining a current signal output.

Furthermore, its characteristic matrix and circuit configuration of a CCII is described in Eq. (1) and Figure 2 [5].

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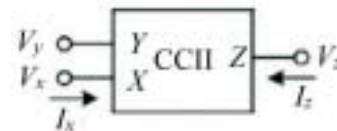


Figure 1. The symbol of a CCII.

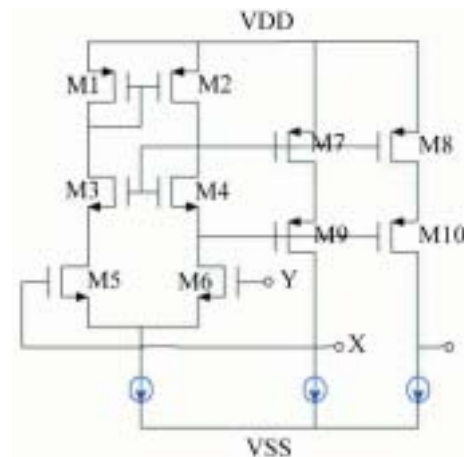


Figure 2. The circuit configuration of a CCII+.

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$$\begin{bmatrix} V_x \\ I_y \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ \pm 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_x \\ V_y \\ V_z \end{bmatrix} \quad (1)$$

where the plus and minus signs denote CCII+ and CCII-, respectively.

The ratio of the resistors in connection with the Z terminal to that with the Y terminal of each CCII is also utilized as an adjusted parameter in the proposed filter.

Figure 3 indicates the symbol of a differential difference current conveyor (DDCC).

In the same manner as CCII does, DDCC owns the advantages of high input impedance at port Y_1, Y_2 and Y_3 and high output impedance at port Z which suit for voltage signal inputs and current signal output.

In this paper, DDCC+ can act as an active element to combine the voltage signals in the signal flow graph. Due to its signal processing function, we can implement the biquadratic filter much easier. Its characteristic matrix and circuit configuration are shown in Eq. (2) and Figure 4 [6].

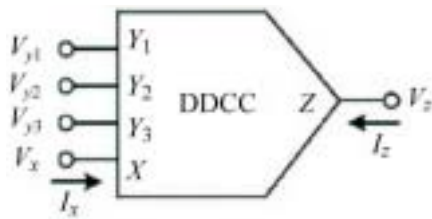


Figure 3. The symbol of a DDCC.

$$\begin{bmatrix} V_x \\ I_{Y1} \\ I_{Y2} \\ I_{Y3} \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 1 & -1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ \pm 1 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_x \\ V_{Y1} \\ V_{Y2} \\ V_{Y3} \\ V_z \end{bmatrix} \quad (2)$$

where the plus and minus signs denote DDCC+ and DDCC-, respectively.

2. Routine Analysis and Circuit Description

The proposed filter configuration is given in Figure 5. Compared to prior some configurations, the advantages of the proposed filter are center frequency and quality factor independently adjustable and all passive

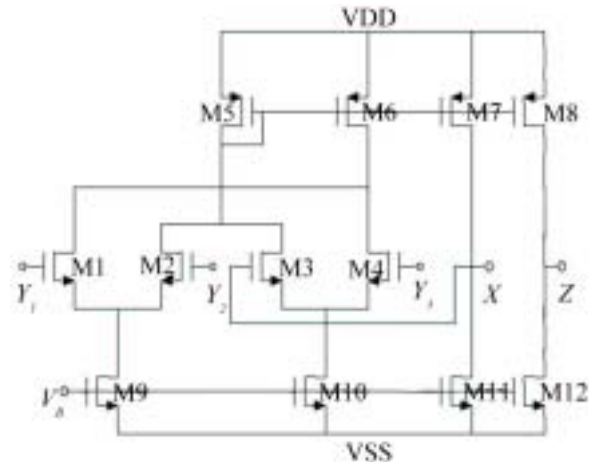


Figure 4. The circuit configuration of a DDCC+.

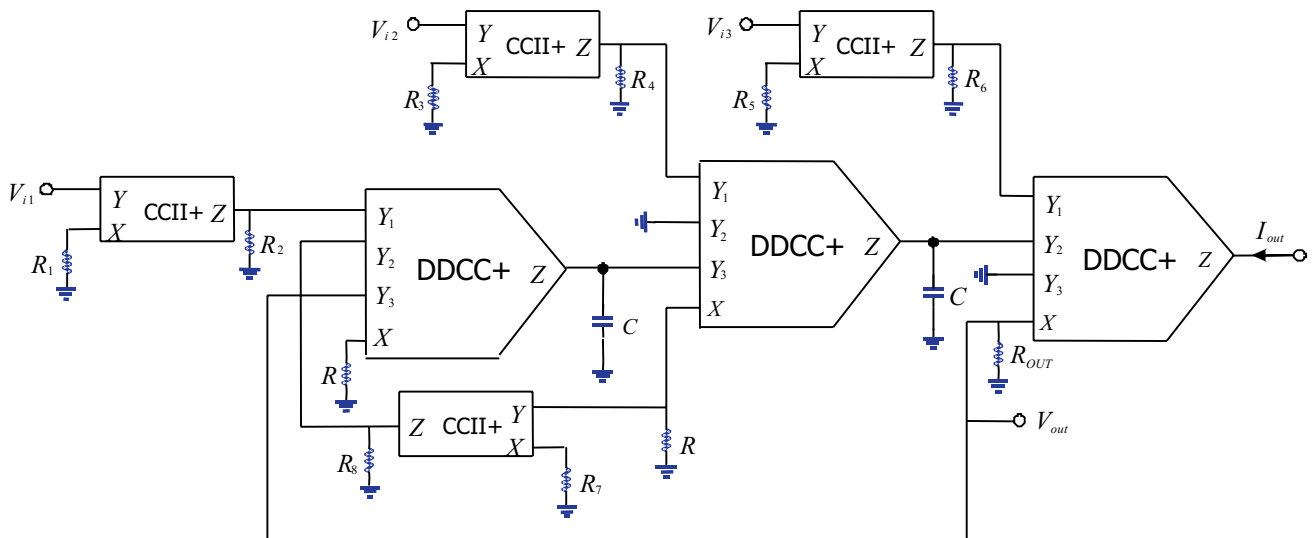


Figure 5. Circuit configuration of proposed biquadratic filter.

components are grounded. According to the signal flow graph of the proposed circuit shown in Figure 6, two integrators and three summers are required to implement such a filter. Using DDCC+, the signal flow graph can be adequately constructed by its equations.

Especially, we use a resistor and a capacitor at each port X and each port Z for both of the first two DDCC+1s, respectively. This connection can be used as an integrator. Finally, Figure 5 can be realized as a filter with three voltage-inputs and one voltage-output and one current-output, and then yields the following transfer function:

$$V_{out} = \frac{s^2 a_2 V_{i3} + s \left(\frac{1}{Q} a_2 \omega_o V_{i3} - a_1 \omega_o V_{i2} \right) - a_o \omega_o^2 V_{i1}}{s^2 + \frac{\omega_o}{Q} s + \omega_o^2} \quad (3)$$

where

$$a_o = \frac{R_2}{R_1}, \quad a_1 = \frac{R_4}{R_3}, \quad a_2 = \frac{R_6}{R_5}$$

$$Q = \frac{R_7}{R_8}, \quad \omega_o = \frac{1}{RC}$$

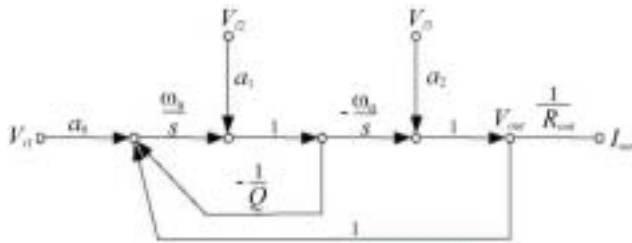


Figure 6. Signal flow graph.

There are three types of biquadratic filters can be realized from Eq. (3) when those three voltage-input-signals are chosen as follows: (For simplification, we choose $a_o, a_1 = 1, a_2 = 1/Q$)

- (1) When $V_{i2} = V_{i3} = 0$ and $V_{i1} = V_{in}$, a lowpass filter can be obtained from V_{out} .
- (2) When $V_{i1} = V_{i3} = 0$ and $V_{i2} = V_{in}$, a bandpass filter can be obtained from V_{out} .
- (3) When $V_{i1} = 0$ and $V_{i2} = V_{i3} = V_{in}$ a highpass filter can be obtained from V_{out} .

Moreover, the angular frequency ω_o and quality factor Q which are independent parameters through the given R, C and R_7, R_8 .

$$\omega_o = \frac{1}{RC} \quad (4)$$

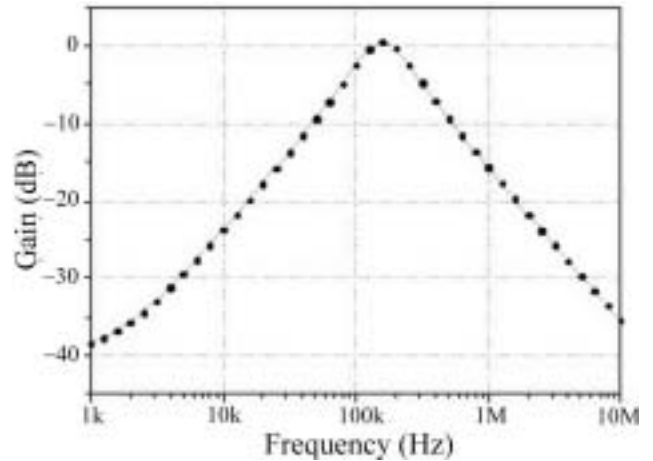


Figure 8. The voltage magnitude response of the bandpass filter.

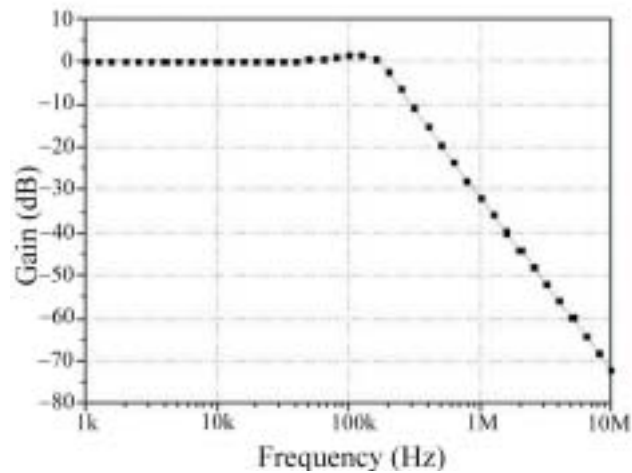


Figure 7. The voltage magnitude response of the lowpass filter.

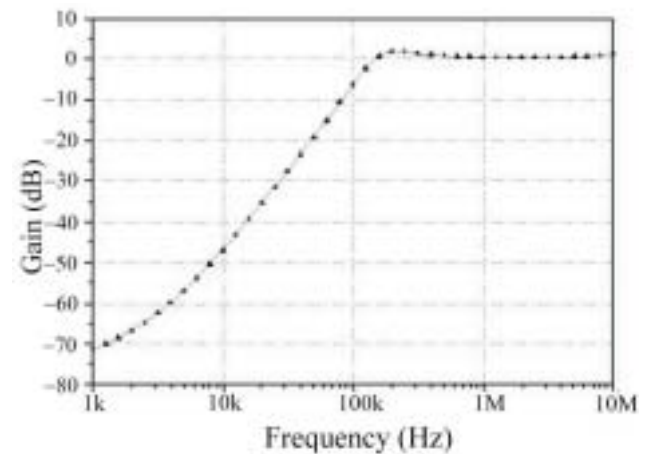


Figure 9. The voltage magnitude response of the highpass filter.

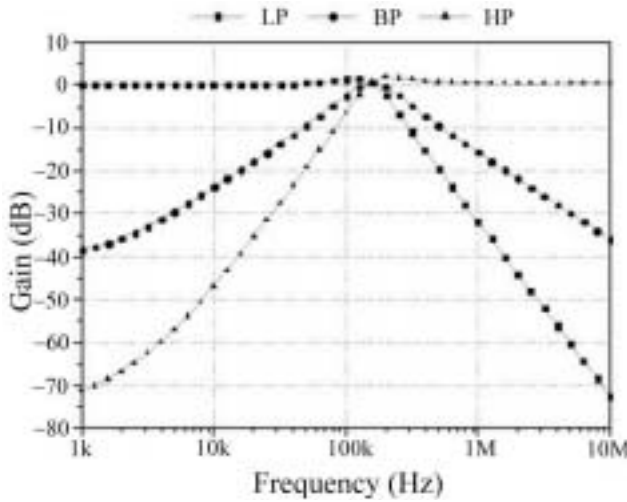


Figure 10. The current magnitude response of the three type filters.

$$Q = \frac{R_7}{R_8} \quad (5)$$

Then the center frequency of three type filters can be easily represented by $1/2\pi RC$.

Sensitivities of ω_0 and Q to the passive elements can be easily obtained from Eq. (4) and Eq. (5).

$$S_R^{\omega_0} = S_C^{\omega_0} = -1$$

$$S_{R_7}^Q = -S_{R_8}^Q = 1$$

The absolute values of the above mentioned sensitivities are equal to 1. Therefore, the ω_0 and Q are insensitive to passive elements.

3. Biquad Realization

In order to verify the theory of the biquadratic filter shown in Figure 5, we use the normal values $V_{DD} = 3.3$ V, $V_{SS} = -3.3$ V, $V_B = -2$ V, $R = 1$ k Ω , $C = 1$ nF and $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R_7 = R_8 = 10$ k Ω .

So we obtained $a_0 = a_1 = a_2 = 1$. The quality factor is $Q = R_7/R_8 = 1$ and center frequency $f_0 = 159.15$ kHz.

The circuit configurations of two types of current conveyors from Figure 2 and Figure 4 are used to constructing the proposed filter in Figure 5. If we choose different RC values then we can obtain different center frequencies in active component frequency range. Finally, Hspice simulation results of three types of filters with

voltage and current magnitude responses using CMOS UMC 0.5 μ m process are shown in Figure 7 to Figure 10.

4. Conclusion

In this paper, we use current conveyors as active components to implement a biquadratic filter. DDCCs and CCIIs are adequately utilized all the flexibility of the circuit. Its angular frequency and quality factor are independent. The simulation results of the three types of filters matched well with the principle of the proposed circuit. Finally, we may modify the DDCC structure for lower capacitor value application and for monolithic integrated circuits implement in the future work.

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