

CASCADABLE CURRENT MODE MULTIFUNCTION BIQUADRATIC FILTER

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ABSTRACT

A novel three inputs and single output current-mode universal biquadratic filter with high-input and high-output impedance using three plus-type differential difference current conveyors, grounded capacitors and resistors is presented. The proposed circuit offers the following features: realization of all the standard filter functions that is high pass, bandpass, lowpass, notch and all pass filters, no requirements for component matching conditions, the use of only grounded capacitors and resistors, high input and high output impedance and low active and passive sensitivities.

Keywords: Active filters, biquadratic filter, current mode circuits, current conveyors, differential difference current conveyor (DDCC)

ÖZET

Üç artı-tip diferansiyel fark akım taşıyıcı, topraklı kapasiteler ve dirençleri kullanarak, yüksek giriş ve çıkış empedansları olan üç girişli ve bir çıkışlı akım modlu yeni bir ikinci derece universal filtre tanıtılmıştır. Önerilen devrenin aşağıdaki özellikleri bulunmaktadır: Yüksek, alçak, band geçiren, band durduran ve tüm geçiren standart filtre fonksiyonlarının hepsi bu devreyle gerçekleştirilebilir. Gerçeklemede elemanlar için denkleştirme koşulları gerekmez ve yalnız topraklı kapasite ve dirençler kullanılır. Devrenin yüksek giriş ve çıkış empedansları, küçük aktif ve pasif duyarlıkları vardır.

Anahtar kelimeler: Aktif filtreler, ikinci dereceden filtreler, Akım modu devreler, Akım taşıyıcılar, Diferansiyel fark akım taşıyıcı

1. INTRODUCTION

Multifunction type active filters are especially versatile, since the same topology can be used for different filter functions. In spite of the fact that numerous current mode multifunction filters are reported in literature, most of them use at least three active elements, and only few can realize all types of current transfer functions using reduced number of active elements.

The applications and advantages in the realization of various active filter transfer functions using current conveyors have received considerable attention [1]. Second order active filters with high input impedance are great of interest because several cells of this kind can be directly connected in cascade to implement higher order filters [2].

Recently, many voltage-mode universal biquadratic filters with three inputs and one output were proposed [3-11]. All circuits employ different types second generation current conveyors (CCIIs) and they are voltage mode circuits. However, none of their responses have the advantage of high input impedance and all pass requires component matching condition. Chang and Tu [9] employed two plus-type CCIIs, two capacitors and three resistors with four inputs and single output to realize a universal biquad. Horng [10-11] proposed two new high input impedance-voltage mode universal biquadratic filters with three inputs and single output using three plus-type CCIIs. However, these circuits employ floating capacitors and need a voltage inverter to realize all pass filter response. Moreover, the active and passive sensitivities are not small.

In this paper, a new high-input and high output impedance current-mode universal biquadratic filter with three inputs and single output using three plus-type differential difference current conveyors (DDCCs) [12] is presented. The new circuit uses two grounded capacitors and five grounded resistors which are suitable for integrated circuit implementation [13]. The circuit needs neither any inverting type voltage input signal nor any

critical component matching conditions. Moreover, the circuit has low active and passive sensitivities.

2. PROPOSED CIRCUIT

The differential difference current conveyor (DDCC) was proposed in 1996 [12], and it enjoys the advantages of CCII and DDA such as larger signal bandwidth, greater linearity, wider dynamic range, simple circuitry, low power consumption, high input impedance and arithmetic operation capability. Moreover, it has three high input voltage terminals (Y terminals) that make it easy to synthesize circuits.

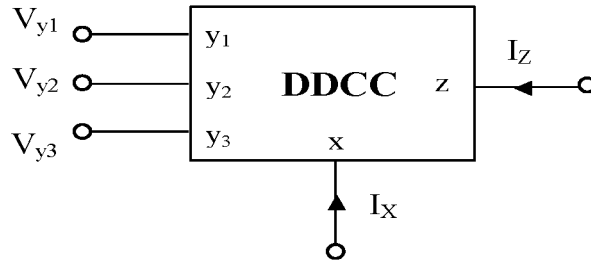


Figure 1. The Symbol of the DDCC

Using standard notation, the port relations of an ideal DDCC shown in Fig.1 can be characterized by

$$\begin{bmatrix} V_x \\ I_{y1} \\ I_{y2} \\ I_{y3} \\ I_z \end{bmatrix} = \begin{bmatrix} 1 & -1 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \pm 1 \end{bmatrix} \begin{bmatrix} V_{y1} \\ V_{y2} \\ V_{y3} \\ I_x \end{bmatrix} \quad (1)$$

where the plus and minus signs indicate whether the conveyor is configured as a noninverting or inverting circuit, termed DDCC+ or DDCC-. The proposed configuration is shown in Fig.2 The transfer functions can be expressed as

$$I_{out} = \frac{s^2 C_1 C_2 I_{in3} - s C_1 G_2 I_{in2} + G_1 G_2 I_{in1}}{s^2 C_1 C_2 + s C_1 G_2 + G_1 G_2} \quad (2)$$

From (2), we can see the following:

- 1) If $I_{in1}=I_{in2}=0$, a second order high pass filter can be obtained with I_{out}/ I_{in3}
- 2) If $I_{in1}=I_{in3}=0$, a second order bandpass filter can be obtained with I_{out}/ I_{in2}
- 3) If $I_{in1}=I_{in3}=0$, a second order bandpass filter can be obtained with I_{out}/ I_{in2}
- 4) If $I_{in2}=I_{in3}=0$, a second order low pass filter can be obtained with I_{out}/ I_{in1}
- 5) If $I_{in2}=0$ and $I_{in1}=I_{in3}=I_{in}$, a second order notch filter can be obtained with I_{out}/ I_{in}
- 6) If $I_{in1}=I_{in2}=I_{in3}=I_{in}$, a second order all pass filter can be obtained with I_{out}/ I_{in}

Thus, the circuit is capable of realing all filter functions. The circuit requires the minimum number of passive components with no requirement for matching conditions. Moreover, the three input signals, I_{in1} , I_{in2} and I_{in3} are connected to the high input impedance input nodes of the three plus-type DDCCs (the y port of the plus-type DDCC), respectively. The output signal, I_{out} is connected to the low output impedance output node of the plus-type DDCC (the z port of the plus-type DDCC).

Cascadable Current Mode Multifunction Biquadratic Filter

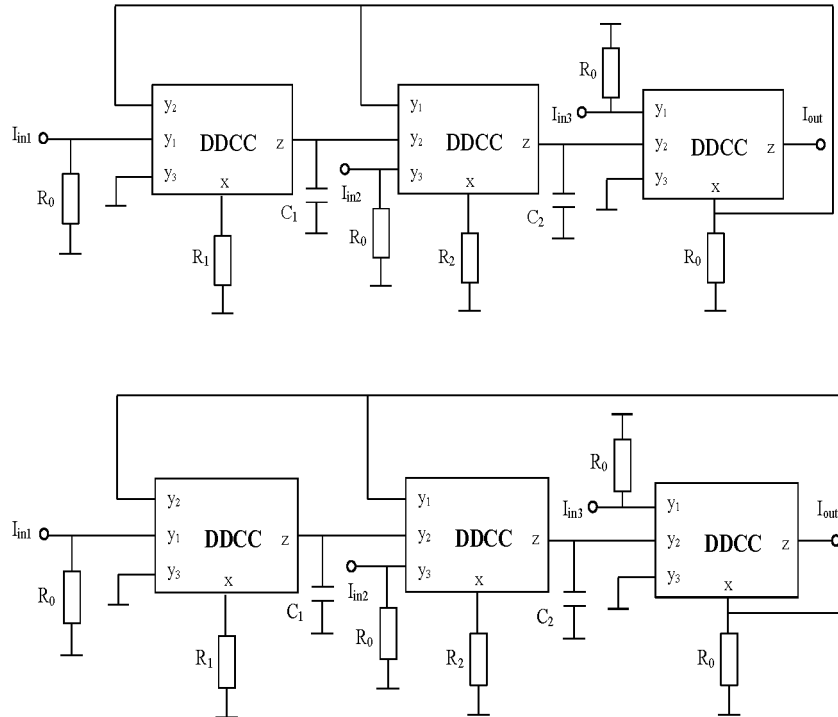


Figure 2. DDCC-based current mode universal biquad

So the circuit enjoys the advantage of having high input and low output impedance. Note that the low output impedance makes the proposed circuit easy to be connected to next stage without any buffer. Furthermore, the new circuit uses only grounded capacitors and resistors, which are suitable for integrated circuit implementation. The employs of only plus type DDCCs simplify the circuit configuration.

3. SENSITIVE ANALYSIS

Taking the nonidealities of the DDCC into account, the relationship of the terminal voltages and currents can be rewritten as

$$\begin{bmatrix} V_x \\ I_{y1} \\ I_{y2} \\ I_{y3} \\ I_z \end{bmatrix} = \begin{bmatrix} \alpha_{k1} & -\alpha_{k2} & \alpha_{k3} & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \pm\beta_k \end{bmatrix} \begin{bmatrix} V_{y1} \\ V_{y2} \\ V_{y3} \\ I_x \end{bmatrix} \quad (3)$$

where $\alpha_{k1} = 1 - \varepsilon_{k1v}$ and $\varepsilon_{k1v} (|\varepsilon_{k1v}| \ll 1)$ denotes the voltage tracking error from V_{y1} terminal to V_x terminal of the k th DDCC, $\alpha_{k2} = 1 - \varepsilon_{k2v}$ and $\varepsilon_{k2v} (|\varepsilon_{k2v}| \ll 1)$ denotes the voltage tracking error from V_{y2} terminal to V_x terminal of the k th DDCC, $\alpha_{k3} = 1 - \varepsilon_{k3v}$ and $\varepsilon_{k3v} (|\varepsilon_{k3v}| \ll 1)$ denotes the voltage tracking error from V_{y3} terminal to V_x terminal of the k th DDCC and $\beta_k = 1 - \varepsilon_{ki}$ and $\varepsilon_{ki} (|\varepsilon_{ki}| \ll 1)$ denotes the current tracking error of the k th DDCC. The denominator of nonideal voltage transfer function in Fig.2 becomes

$$D(s) = s^2 C_1 C_2 + s C_1 G_2 \alpha_{21} \alpha_{32} \beta_2 + G_1 G_2 \alpha_{12} \alpha_{22} \alpha_{32} \beta_1 \beta_2 \quad (4)$$

The resonance angular frequency w_o and quality factor Q are obtained by

$$w_o = \sqrt{\frac{G_1 G_2 \alpha_{12} \alpha_{22} \alpha_{32} \beta_1 \beta_2}{C_1 C_2}} \quad (5)$$

$$Q = \frac{1}{\alpha_{21}} \sqrt{\frac{C_2 G_1 \alpha_{12} \alpha_{22} \beta_1}{C_1 G_2 \alpha_{32} \beta_2}} \quad (6)$$

The active and passive sensitivities of w_o and Q are calculated as

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$$S^{w_o}_{\alpha_{12}, \alpha_{22}, \alpha_{32}, \beta_1, \beta_2} = S^{w_o}_{G_1, G_2} = -S^{w_o}_{C_1, C_2} = \frac{1}{2},$$

$$S^Q_{\alpha_{12}, \alpha_{22}, \beta_1} = -S^Q_{\alpha_{32}, \beta_2} = S^{w_o}_{C_2, G_1} = -S^{w_o}_{C_1, G_2} = \frac{1}{2},$$

$$S^Q_{\alpha_{21}} = -1.$$

All the active and passive absolute sensitivities are equal are less than one.

4. SIMULATION RESULTS

The proposed circuit was simulated using PSPICE. The DDCC was realized by the CMOS implementation using TSMC 0.35- μm CMOS technology process parameters [14]. Aspect ratios of the MOS transistors were chosen in Table I [12] and the power supply was ± 1.65 V. The biasing voltage V_b was taken as -0.76 V. Fig.3a,b,c,d, and e, respectively, represents the simulated amplitude frequency responses and phase frequency responses for LP, HP, BP, notch and all pass filters which designed with $f_o=159$ kHz, $C_1=C_2=1$ nF, $R_0=10$ k Ω and $R_1=R_2=1$ k Ω . Furthermore, to demonstrate the performance of higher order filter which is made up more than one cascaded biquad filter sections, cascaded two and three BP filter sections having the same component values given above are simulated with PSPICE and simulation results are shown in Fig.4. All simulation results are in good agreement with the predicted theory. Actually, the parasitic resistances and capacitances, and nonidealities of the DDCCs cause the small deviations from the theoretical values in the frequency responses of the simulated filters.

5. CONCLUSION

In this study, a new three inputs and single output current mode universal biquadratic filter with high input and high output impedance is presented. The proposed circuit uses three plus type

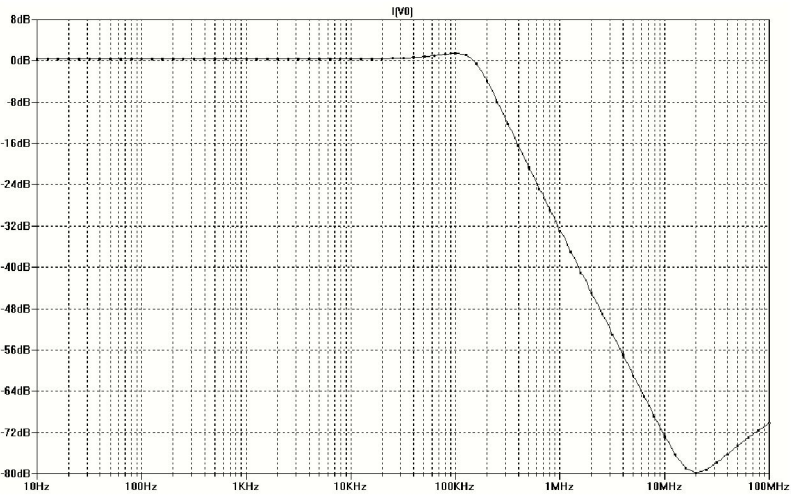


Figure 3a. PSPICE simulation results for the LP filter

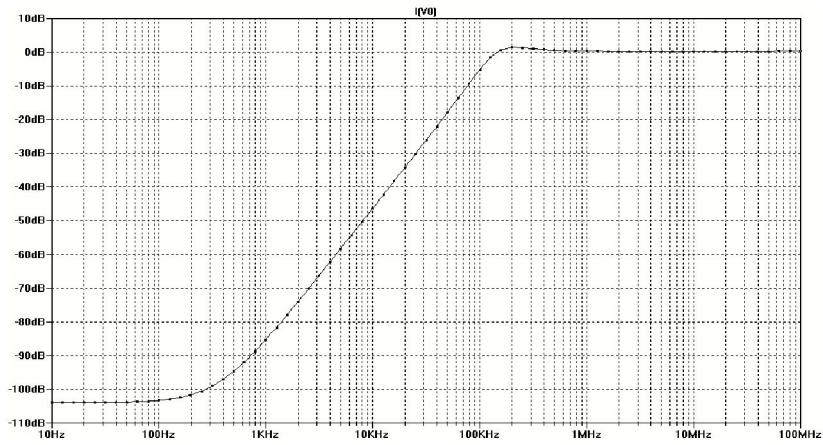


Figure 3b. PSPICE simulation results for the HP filter

Figure

Cascadable Current Mode Multifunction Biquadratic Filter

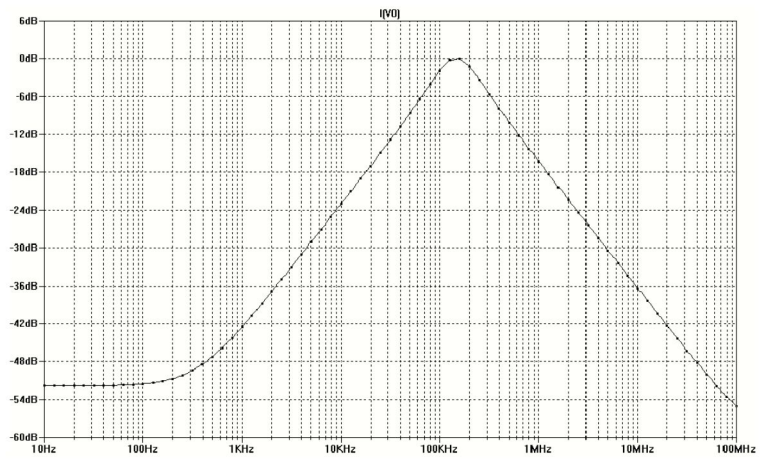


Figure 3c. PSPICE simulation results for the BP filter

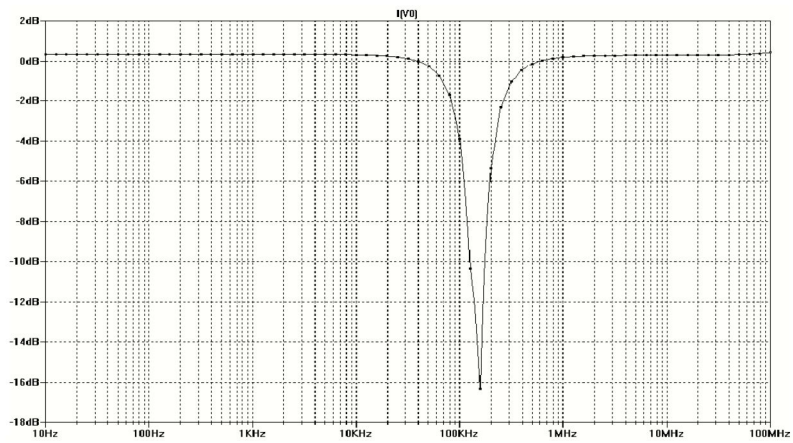


Figure 3d. PSPICE simulation results for the Notch (BS) filter

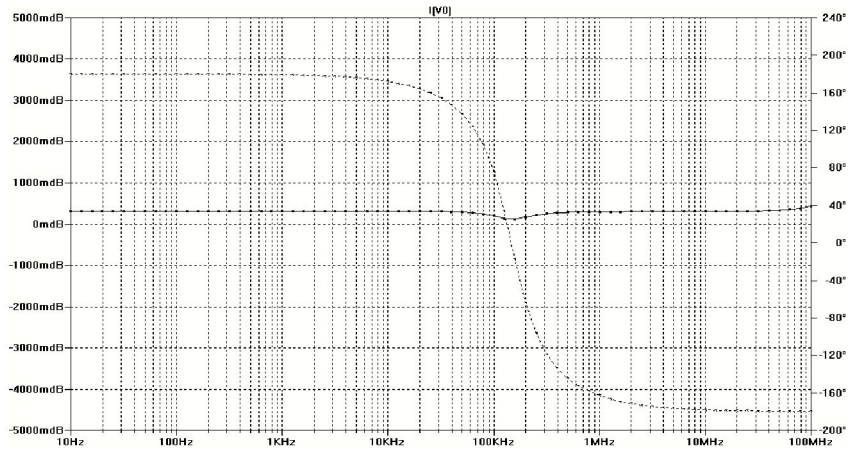


Figure 3e. PSPICE simulation results for the AP filter

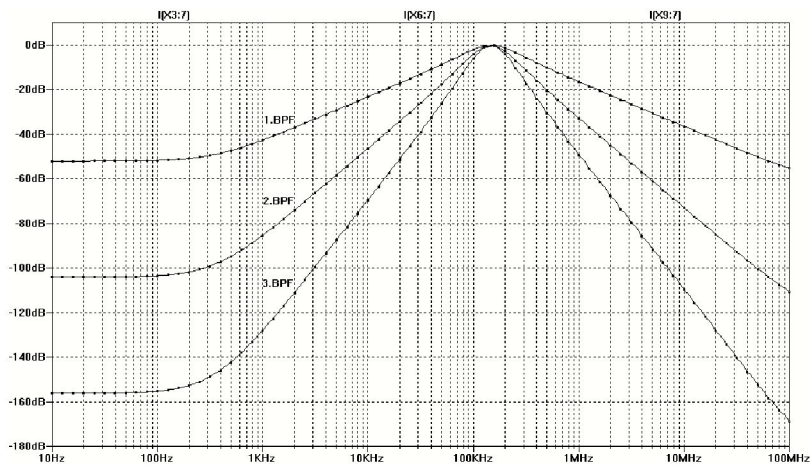


Figure 4. PSPICE simulation results for the cascaded BP biquad filter sections

DDCCs, two grounded capacitors and five grounded resistors and also offers following advantages: high input and high output impedance which is cascadeable without any buffer, low active and passive sensitivities, the use of only three plus type DDCCs that simplifies the circuit configuration, the use of only grounded capacitors and resistors which are suitable for integrated circuit implementation, the versatility to synthesize low pass, bandpass, high pass, notch and all pass responses without component matching conditions.

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