Three Inputs and One Output Voltage-Mode Universal Biquadratic Filter Using One CCII and One CCIII

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***Abstract*—A voltage-mode universal biquadratic filter using one second-generation current conveyor (CCII), one third-generation current conveyor (CCIII), two capacitors and two resistors is presented. The proposed voltage-mode biquadratic circuit has three input terminals and one output terminal and can realize all the standard filter functions that are highpass, bandpass, lowpass, notch and allpass filters without changing the circuit topology. Both its active and passive sensitivities are small. The proposed circuit does not need one more active component for the unity-gain inverting of the input signal in each filter realization.**

***Index Terms*—Voltage-mode; Biquadratic filter; Active circuit; Current conveyor.**

I. Introduction

Active filters are so widely used in consumer electronics, telecommunications and many electronic systems [1-3]. Current conveyor has potential advantages in wider dynamic range, greater linearity, wide bandwidth and simple circuitry that make it attractive in circuit design [4-6]. Many voltage-mode universal biquadratic filters with multi-input terminals were proposed [7-25]. From the different combinations of injection of input voltage signals, voltage-mode lowpass, bandpass, highpass, notch and allpass filters can be obtained without changing the circuit topology. However, the universal biquadratic circuits in [7-11] require at least three active components. The universal biquadratic circuits in [12-14] require two active and five passive components. The universal biquadratic circuits in [15-21] require one more active component for the unity-gain inverting input in some filter type realizations. Each voltage-mode universal biquad in [22-24] requires one more active component for amplifying the input signal in the notch or allpass filter realizations. In 2010, Horng proposed a voltage-mode universal biquad with three inputs and two outputs using two resistors, two capacitors and one CCII [25]. However, the active and passive sensitivities maybe high when choosing some passive element values.

In this paper, a new voltage-mode universal biquadratic filter is presented. The proposed circuit uses one second-generation current conveyor (CCII), one third-generation current conveyor (CCIII), two capacitors and two resistors. It has three input terminals and one output terminal and can realize all the standard filter functions that are highpass, bandpass, lowpass, notch and allpass filters without changing the circuit topology. With respect to the previous universal biquads in [7-11], the proposed circuit employs one less active component. With respect to the previous universal biquads in [12-14], the proposed circuit employs one less resistor. With respect to the previous universal biquads in [15-21], the proposed circuit need not one more active component for the unity-gain inverting input in the realizations of some filter types. With respect to the previous universal biquads in [22-24], the proposed circuit need not one more active component for amplifying the input signal in the realizations of some filter types. With respect to the previous universal biquad in [25], the active and passive sensitivities of the proposed circuit are low.

II. Proposed circuit

Using standard notation, the port relations of a CCII can be characterized by $i_y = 0$, $v_x = v_y$ and $i_z = \pm i_x$. The port relations of a CCIII can be characterized by $i_y = -i_x$, $v_x = v_y$ and $i_z = \pm i_x$. Considering the proposed voltage-mode circuit in Fig. 1, the output voltage V_o can be expressed as

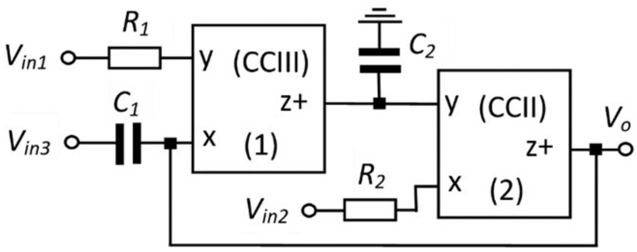

Fig. 1 Proposed voltage-mode universal biquadratic filter.

$$V_o = \frac{s^2C_1C_2V_{in3} - sC_2G_2V_{in2} + sC_2G_1V_{in1} + G_1G_2V_{in1}}{s^2C_1C_2 + sC_2G_1 + G_1G_2} \quad (1)$$

From (1), we can see that:
(i) If $V_{in1} = V_{in2} = 0$ (grounded), V_{in3} = input voltage signal, a highpass filter can be obtained;
(ii) If $V_{in1} = V_{in3} = 0$ (grounded), V_{in2} = input voltage signal, a bandpass filter can be obtained;
(iii) If $V_{in3} = 0$ (grounded), $G_2 = G_1$, $V_{in1} = V_{in2}$ = input voltage signal, a lowpass filter can be obtained;
(iv) If $G_2 = G_1$, $V_{in1} = V_{in2} = V_{in3}$ = input voltage signal, a notch filter can be obtained;
(v) If $G_2 = 2G_1$, $V_{in1} = V_{in2} = V_{in3}$ = input voltage signal, an allpass filter can be obtained.

Thus, the circuit is capable of realizing all voltage-mode filter functions. The proposed circuits in Fig. 1 uses two resistors, two capacitors, one CCII and one CCIII. The proposed circuit does not need one more active component for the unity-gain inverting of the input signal or amplifying the input signal in each filter realization.

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Taking into account the nonideal current conveyors, the characteristics of the non-ideal CCIII(1)+ can be given by namely $i_y = -\gamma_1 i_x$, $i_z = \alpha_1 i_x$ and $v_x = \beta_1 v_y$, where $\gamma_1 = 1-\ \varepsilon_{11}$ and ε_{11} ($|\varepsilon_{11}|$<<1) denotes the input current tracking error, $\alpha_1 = 1-\varepsilon_{12}$ and ε_{12} ($|\varepsilon_{12}|$<<1) is the output current tracking error, $\beta_1 = 1-\varepsilon_{13}$ and ε_{13} ($|\varepsilon_{13}|$ <<1) is the input voltage tracking error of the CCIII(1)+. The characteristics of the non-ideal CCII(2)+ can be given by namely $i_y = 0$, $i_z = \alpha_2 i_x$ and $v_x = \beta_2 v_y$, where $\alpha_2 = 1-\ \varepsilon_{21}$ and ε_{21} ($|\varepsilon_{21}|$<<1) denotes the output current tracking error, $\beta_2 = 1-\ \varepsilon_{22}$ and ($|\varepsilon_{22}|$ <<1) is the input voltage tracking error of the CCII(2)+.The denominator of the output voltage in Fig. 1 becomes

$$D(s) = s^2 C_1 C_2 \beta_1 \gamma_1 + sC_2 G_1 + G_1 G_2 \alpha_1 \alpha_2 \beta_2 \quad (2)$$

The parameters ω_o and Q can be expressed as

$$\omega_o = \sqrt{\frac{\alpha_1 \alpha_2 \beta_2}{C_1 C_2 R_1 R_2 \beta_1 \gamma_1}} \quad (3)$$

$$Q = \sqrt{\frac{C_1 R_1 \alpha_1 \alpha_2 \beta_1 \beta_2 \gamma_1}{C_2 R_2}} \quad (4)$$

The active and passive sensitivities of this universal bi-quadratic filter are

$$S^{\omega_o}_{\alpha_1,\alpha_2,\beta_2} = -S^{\omega_o}_{C_1,C_2,R_1,R_2,\beta_1,\gamma_1} = \frac{1}{2}$$

$$S^{Q}_{C_1,R_1,\alpha_1,\alpha_2,\beta_1,\beta_2,\gamma_1} = -S^{Q}_{C_2,R_2} = \frac{1}{2}$$

The active and passive sensitivities are low.

III. Simulation Results

The proposed circuit was simulated in HSPICE using 0.18 µm, level 49 MOSFET parameters from TSMC. The CMOS CCII has been shown in Fig. 2 [26]. The dimensions of the NMOS transistors in the CCII are set to be W = 4.5µm and L = 0.9µm. The dimensions of the PMOS transistors in the CCII are set to be W = 9µm and L = 0.9µm. The supply voltages are V+ = +0.9V, V- = -0.9V and V_{b1} = -0.38V. The CCIII+ was obtained by two outputs CCII and is shown in Fig. 3.

Fig. 4 represents the simulated frequency responses for the highpass filter design with $V_{in1} = V_{in2} = 0$ (grounded), $V_{in3} = V_{in}$, $C_1 = C_2$ = 100pF and $R_1 = R_2$ =10kΩ. Fig. 5 represents the simulated frequency responses for the band-pass filter design with $V_{in1} = V_{in3} = 0$ (grounded), $V_{in2} = V_{in}$, $C_1 = C_2$ = 100pF and $R_1 = R_2$ = 10kΩ. Fig. 6 represents the simulated frequency responses for the lowpass filter design with $V_{in3} = 0$ (grounded), $V_{in1} = V_{in2} = V_{in}$, $C_1 = C_2$ = 100pF and $R_1 = R_2$ =10kΩ. Fig. 7 represents the simulated frequency responses for the notch filter design with $V_{in1} = V_{in2} = V_{in3} = V_{in}$, $C_1 = C_2$ = 100pF and $R_1 = R_2$ = 10kΩ. Fig. 8 represents the simulated frequency responses for the allpass filter design with $V_{in1} = V_{in2} = V_{in3} = V_{in}$, $C_1 = C_2$ = 100pF and R_1 = 20kΩ and R_2 = 10kΩ. The results confirm the theoretical analyses.

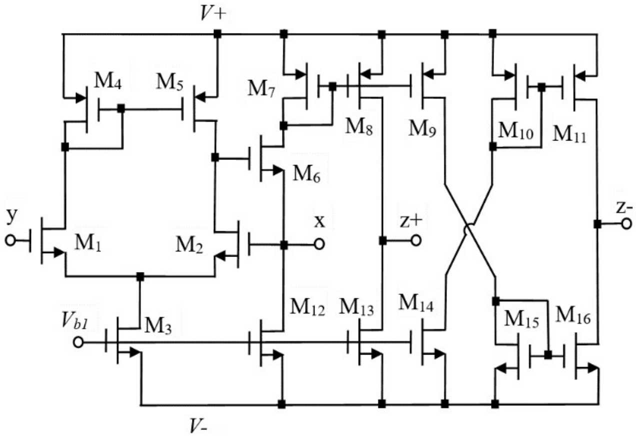

Fig. 2 The CCII CMOS realization [26].

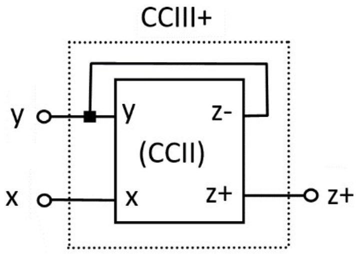

Fig. 3 The implementation of CCIII+ by using two outputs CCII.

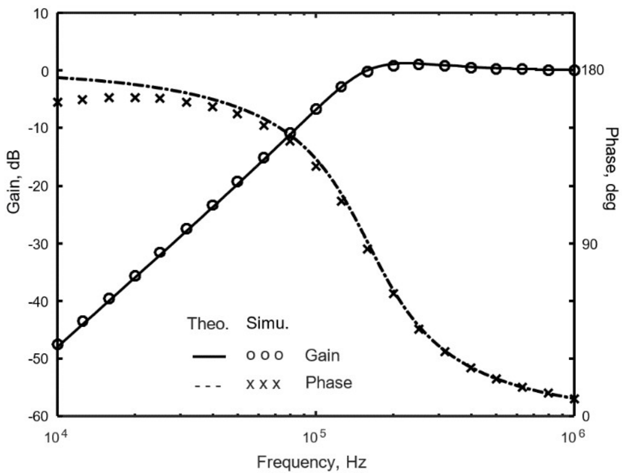

Fig. 4 Simulated frequency responses for the highpass filter of Fig. 1.

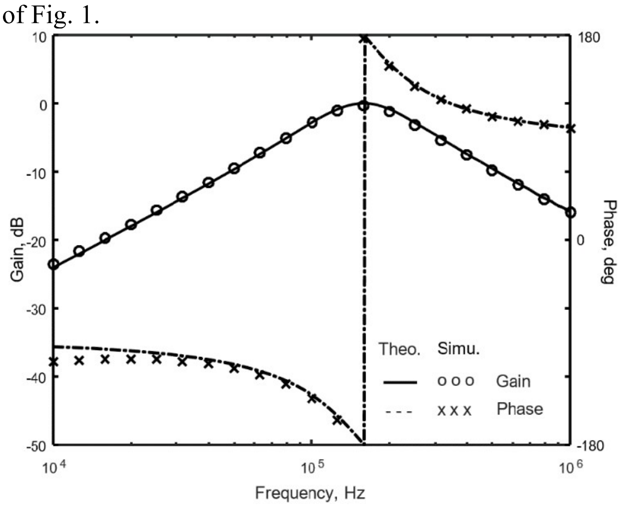

Fig. 5 Simulated frequency responses for the bandpass filter of Fig. 1.

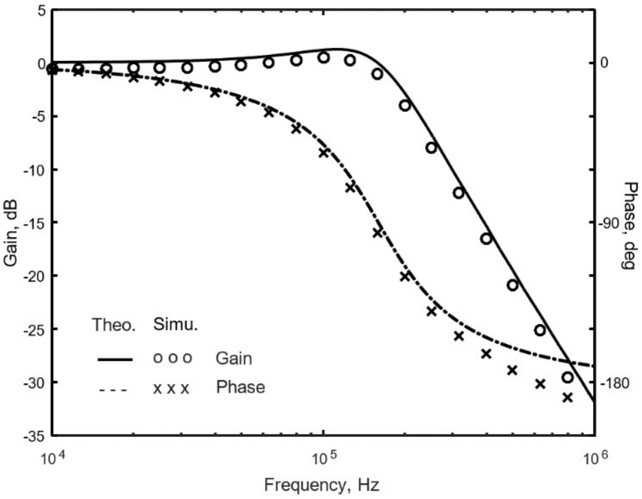

Fig. 6 Simulated frequency responses for the lowpass filter of Fig. 1.

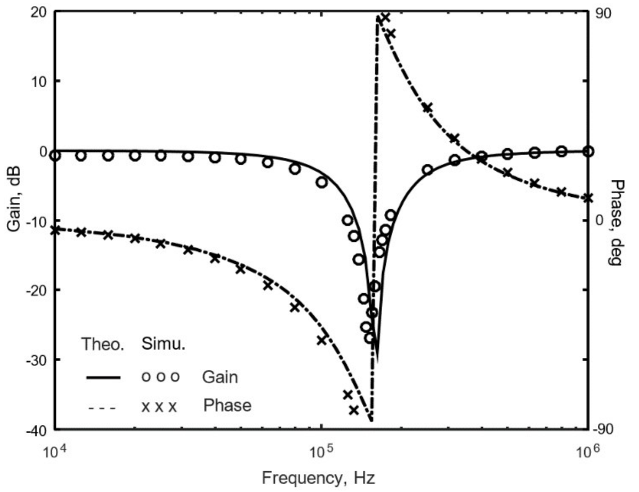

Fig. 7 Simulated frequency responses for the notch filter of Fig. 1.

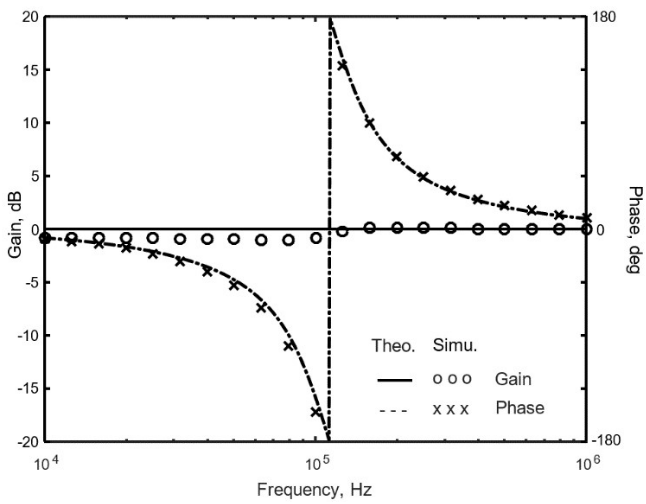

Fig. 8 Simulated frequency responses for the allpass filter of Fig. 1.

IV. CONCLUSIONS

A new current conveyors based voltage-mode universal biquadratic filter has been presented. The new circuit has three input terminals and one output terminal employs two capacitors, two resistors, one CCII and one CCIII. All standard filter functions that are highpass, bandpass, lowpass, notch and allpass filters can be obtained without changing the circuit topology. The proposed circuit uses only four passive components. It needs not one more active component for the unity-gain inverting of the input signal or amplifying the input signal in each filter realization. The active and passive sensitivities are low.

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