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High output impedance current-mode universal filter

N A Shah, M F Rather & S Z Iqbal

Department of Electronics and Instrumentation Technology
The University of Kashmir, Srinagar 190 006
E-mail: farsgr@yahoo.co.in

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A new current-mode universal filter with single input and three outputs employing two second-generation current conveyors (CCIIs), one current follower (CF) and four grounded/virtually grounded passive elements is presented. The proposed circuit enjoys the following features: simultaneous realization of lowpass(LP), bandpass(BP), and highpass(HP) filtering responses, no need of matching conditions, employment of grounded resistors which are ideal for IC implementation, employment of grounded/virtually grounded capacitors, orthogonal control of ω_0 and ω_0 / Q, high output impedance suiting cascadibility for higher order filters, and low passive sensitivity. PSPICE simulation results are included, confirming the workability of the proposed circuit.

Keywords: Current-mode universal filter, Second generation current conveyors, Current follower

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Current-mode circuits are receiving significant attention owing to their larger dynamic range, higher band width, greater linearity, simpler circuitry and lower power consumption than their voltage-mode counterparts[1-5]. A number of universal current-mode filters with either a single input and three outputs, three inputs and one output, two inputs and three outputs or three inputs and two outputs were reported. Abuel'maatti and Khan proposed single input and three outputs using one OTA, three CCIIs and five grounded passive components[6]. Senani[7] proposed single input and three outputs using seven current conveyors and as many grounded passive elements. Chang[8] proposed two circuits with single input and three outputs using excessive number of active and passive grounded elements[9]. Chang *et al.*[10,11] proposed two more configurations having three inputs and one output employing excessive number of passive and active elements. In this note, a new universal current-mode biquad with a single input and three outputs using one current follower, two second-generation current conveyors and four grounded/virtually grounded passive elements is proposed. The circuit implements LP, BP and HP filtering signals simultaneously and the other two responses notch and AP can be realized by connecting the appropriate node currents. The notch and AP responses can be realized from the same configuration and there is no need to impose constraints on the elemental values and/or employment of additional components. The added advantage of the circuit is its cascadibility feature due to availability of output currents at high impedances.

Circuit description—Using the standard notation, the second-generation current conveyors (CCII) and current follower (CF) are characterized by the following port relations respectively.

$I\mathrm{y} = 0,\ V\mathrm{x} = V\mathrm{y}$ and $I\mathrm{z} = \pm I\mathrm{x}$

$V\mathrm{x} = 0,\ V\mathrm{y} = 0$ and $I\mathrm{z} = \pm I\mathrm{x}$

where the ± sign depicts the polarity of the device.

After routine analysis, the circuit yields the following current transfer functions:

$$I_{HP}/I_{IN} = s^2 C_1 C_2 / D(\mathrm{s}) \quad \ldots (1)$$

$$I_{LP}/I_{IN} = (1 / R_1 R_2) / D(\mathrm{s}) \quad \ldots (2)$$

$$I_{BP}/I_{IN} = (-sC_2 / R_1) / D(\mathrm{s}) \quad \ldots (3)$$

where $D(\mathrm{s}) = (s^2 C_1 C_2 + sC_2 / R_1 + 1 / R_1 R_2)$

The notch filtering signal can be implemented simply by connecting together I_{HP} and I_{LP} and is given by

$$I_N / I_{IN} = (I_{HP} + I_{LP}) / I_{IN} = (s^2 C_1 C_2 + 1 / R_1 R_2)/D(\mathrm{s}) \quad \ldots (4)$$

Similarly, by connecting together I_{HP} , I_{BP} and I_{LP}, an AP response is obtained:

$$I_{AP} / I_{IN} = (I_{HP} + I_{BP} + I_{LP}) / I_{IN} = (s^2 C_1 C_2 - sC_2 / R_1 + 1 / R_1 R_2) / D(\mathrm{s}) \quad \ldots (5)$$

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

$$\omega_0 = (1/C_1 C_2 R_1 R_2)^{1/2} \quad \ldots (6)$$

$$\omega_0 / Q = (1 / C_1 R_1) \quad \ldots (7)$$

$$Q = (R_1 C_1 / R_2 C_2)^{1/2} \quad \ldots (8)$$

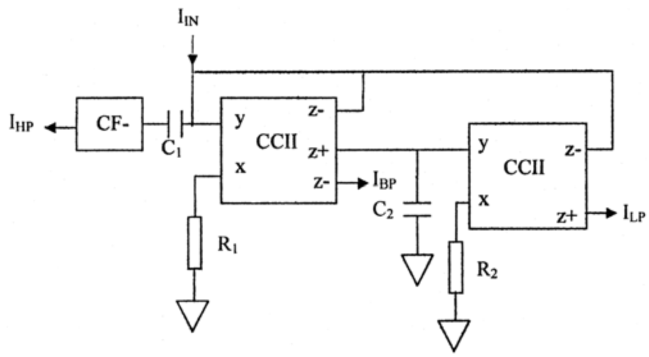

Fig. 1—Proposed universal filter

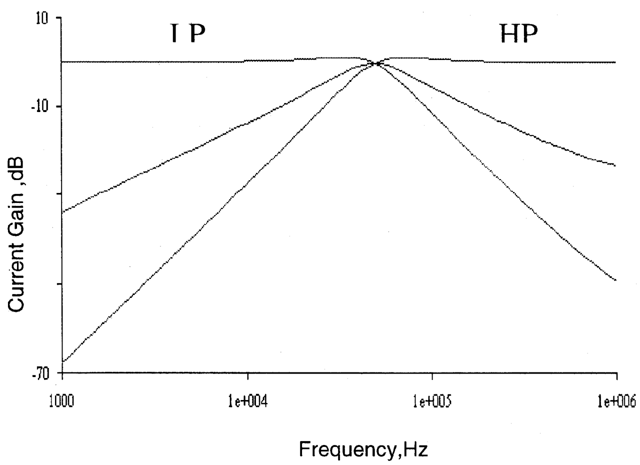

Fig. 2—LP, BP & HP responses

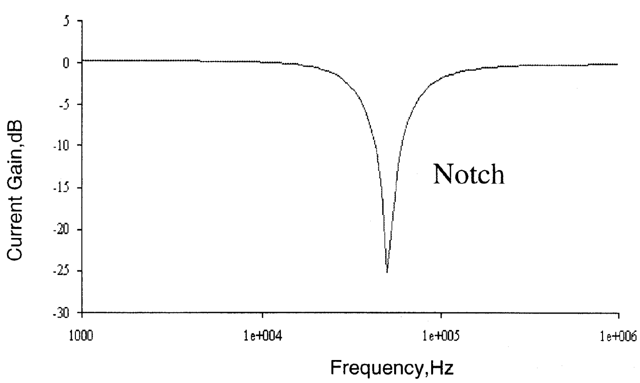

Fig. 3—Notch response

An examination of Eqs (6) and (7) reveals that ω_0 / Q is adjusted by grounded resistor R_1 and ω_0 by grounded resistor R_2 without effecting ω_0 / Q in that order.

Sensitivity—Sensitivity analysis with respect to passive elements yield

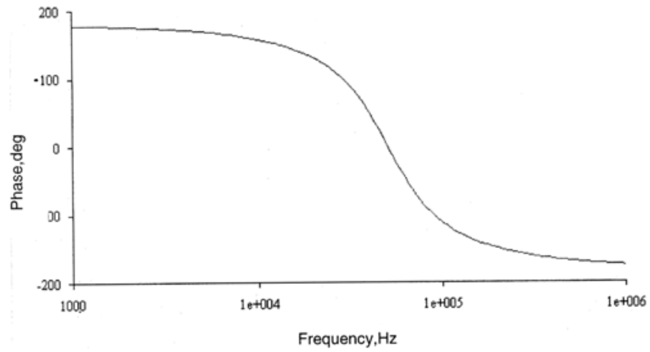

Fig. 4—Phase response for AP

$$S^{\omega 0}_{R1,R2,C1,C2} = -1/2$$

$$S^{\omega 0/\,Q}_{R1,C1} = -1$$

$$S^{Q}_{R1,C1} = -S^{Q}_{R2,C2} = 1/2$$

which are no more than unity in magnitude.

Simulation results—To verify the validity of theoretical results of the proposed filter in Fig.1, PSPICE simulation was carried out. The multi-output CCII was simulated using a modified version of the single output CCII model used by Svobada [12] with dc supply ± 10V. The setting was selected to obtain LP, BP, HP, notch and AP with a natural frequency f_o = 53 kHz and quality factor Q = 1, leading to the following passive elemental values $R_1 = R_2 = 1$ kΩ and $C_1 = C_2 = 3$ nF. The simulated frequency responses of the proposed filter are shown in Figs 2-4 which are in close agreement with theoretical results. However, in higher frequency region, theoretical and simulated results differ which is attributed to the parasitic impedances of the active elements.

Conclusion—A new current-mode universal filter with a single input and three outputs, implementing all the five generic filtering responses is presented. The circuit is constructed around one current follower, two current conveyors and four grounded/virtually grounded passive elements. The circuit has the following salient features: simultaneous realization of LP, HP, and BP responses all at high impedances and free from matching constraints. The circuit enjoys low sensitivity figures. The simulated results are in close agreement with the theoretical calculations.

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