A New Current-Mode Current-Controlled Current-Conveyor Based Universal Filter

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Abstract
A new mixed-mode biquad circuit is presented. The circuit uses six second-generation current-controlled current-conveyors (CCIIs), and two grounded capacitors and can realize lowpass, highpass, bandpass, notch, lowpass notch, highpass notch and allpass responses from the same topology. The low-pass gain, high-pass gain , bandpass gain and the parameters ω_o and ω_o / Q_o enjoy orthogonal electronic tunability. Simulation results are included.

I. Introduction

Universal active filters using the operational transconductance amplifier (OTA) have many advantages, such as simplicity, integratability and programmability [1]-[5]. However, they have some problems with dynamic range and at high frequencies of operation. On the other hand, current-mode current-conveyor based filters can offer wider signal bandwidths, greater linearity and larger dynamic ranges of operation [6],[7]. However, they lack programmability. While programmability can be achieved by combining current conveyors and OTAs [8], the second-generation current-controlled current-conveyor (CCCII) [9] allows current conveyor applications to be extended to the domain of electronically programmable functions. Electronic programmability of the CCCII is attributed to the dependence of the parasitic resistance at port X on the bias current pf the current-conveyor.

Using the CCCII a number of circuit realizations for universal current-mode filters were proposed; see for example [10]-[16] and the references cited therein. However, none of the circuits available in the literature can realize lowpass, highpass, bandpass, allpass, notch, highpass notch and lowpass notch functions from the same topology.

It is the major intention of this paper to present such a generalized current-mode circuit using single-output CCCIIs.

II. Proposed Circuit

The proposed circuit is shown in Fig. 1. Routine analysis assuming that $v_x = v_y + i_x R_x$ where $R_x = V_T / 2I_o$ and I_o is the bias current of the CCCII, yields the transfer functions given by

$$I_{output} = \frac{R_{x6}}{R_{x2}} \frac{s^2 \frac{R_{x4}}{R_{x6}} I_{in2} + s \frac{R_{x4}}{R_{x3} R_{x6} C_1} I_{in3} - \frac{R_{x4}}{R_{x3} R_{x5} R_{x6} C_1 C_2} I_{in1}}{s^2 + s \frac{R_{x2}}{R_{x3} R_{x6} C_1} + \frac{R_{x4}}{R_{x1} R_{x3} R_{x5} C_1 C_2}} \qquad (1)$$

where R_{xi} is the resistance of the x-terminal of the ith CCCII.

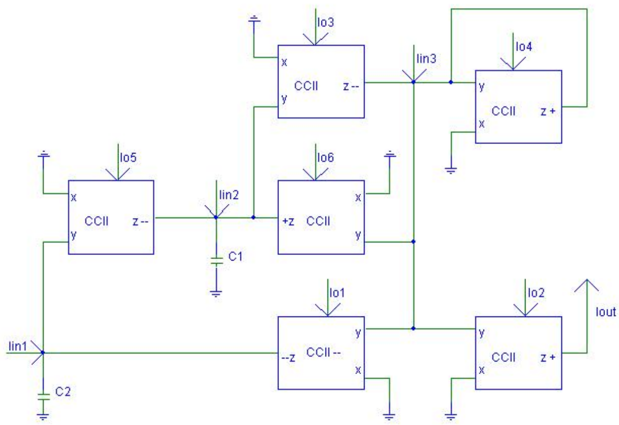

Fig. 1 Proposed current-controlled current-conveyor-based current-mode universal filter

Inspection of equation (1) shows that the following filter functions can be realized:

1. A non-inverting highpass-filter (HPF) with $I_{in1} = I_{in3} = 0$.
2. A noninverting bandpass-filter (BPF) with $I_{in1} = I_{in2} = 0$.
3. An inverting lowpass-filter (LPF) with $I_{in2} = I_{in3} = 0$.
4. A non-inverting notch-filter (NF) with $I_{in3} = 0, I_{in1} = -I_{in2}$.
5. In case 4 , lowpass-notch and highpass-notch can be obtained by adjusting R_{x1} and R_{x4}.
6. An allpass-filter (APF) with $I_{in1} = -I_{in2} = I_{in3}$ and $R_{x1} = R_{x2} = R_{x4} = R_{x6}$.

Inspection of equation (1) shows that, in all cases the parameters ω_o^2 and ω_o / Q_o are given by

$$\omega_o^2 = \frac{R_{x4}}{R_{x1}R_{x3}R_{x5}C_1C_2} = \frac{I_{o1}I_{o3}I_{o5}}{I_{o4}C_1C_2} \tag{2}$$

and

$$\frac{\omega_o}{Q_o} = \frac{R_{x2}}{R_{x3}R_{x6}C_1} = \frac{I_{o3}I_{o6}}{I_{o2}C_1} \tag{3}$$

Also, inspection of equation (1) shows that the higpass-gain of the HPF is given by

$$G_{HP} = \frac{R_{x4}}{R_{x2}} = \frac{I_{o2}}{I_{o4}} \tag{4}$$

the lowpass-gain of the LPF is given by

$$G_{LP} = \frac{R_{x4}^2}{R_{x2}R_{x6}} = \frac{I_{o2}I_{o6}}{I_{o4}^2} \tag{5}$$

the bandpass-gain at the center frequency ω_o is given by

$$G_{BP} = \frac{R_{x1}}{R_{x2}} = \frac{I_{o2}}{I_{o1}} \tag{6}$$

Inspection of equations (2)-(6) shows that the center frequency ω_o can be controlled by adjusting the biasing current I_{o5} without disturbing the bandwidth ω_o / Q_o or any of the gains. However, the bandwidth and the gains can not be controlled without disturbing each other and the center frequency. Thus, a possible strategy for controlling the parameters of the filters is to start by controlling G_{HP} by adjusting I_{o2} and I_{o4}. Then G_{LP} and G_{BP} can be controlled by adjusting I_{o6} and I_{o1} respectively. The bandwidth can be controlled by adjusting I_{o3} and finally, the center frequency can be independently controlled by adjusting I_{o5}.

III. SIMULATION RESULTS

The universal filter circuit shown in Fig. 1 has been simulated using HSPICE circuit simulation program. The CCCII has been simulated using the schematic implementation proposed in [9] with dc supply voltage = $\pm 2.5V$. The results obtained with $C_1 = C_2 = 10nF, R_{xm} = 100\Omega, m = 1,2,...,6$ are shown in Figs. 2-5 where the theoretical results are also shown. It appears from Figs. 2-5 that the simulation and theoretical results are in fairly good agreement.

IV. CONCLUSION

In this paper a novel current-mode current-controlled current-conveyor-based universal filter circuit has been presented. The circuit uses six current-controlled second-generation current-conveyors and two grounded capacitors and can realize all the standard biquad filter responses, that is lowpass, highpass, bandpass, allpass, notch, lowpass notch and highpass notch from the same topology by programming the input currents. The parameters of the filter responses enjoy independent electronic tunability and low passive sensitivities. The simulation results obtained confirm the presented theory.

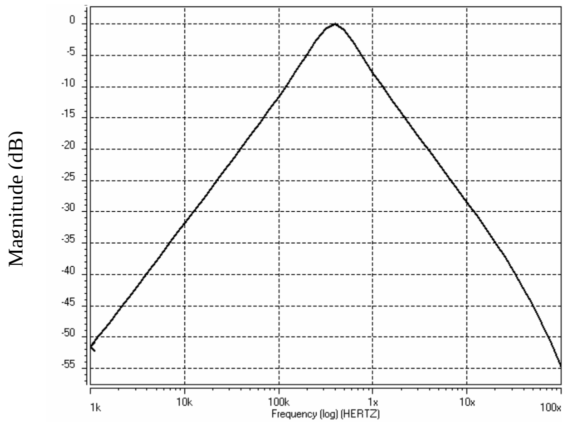

Fig. 2 Simulated bandpass response

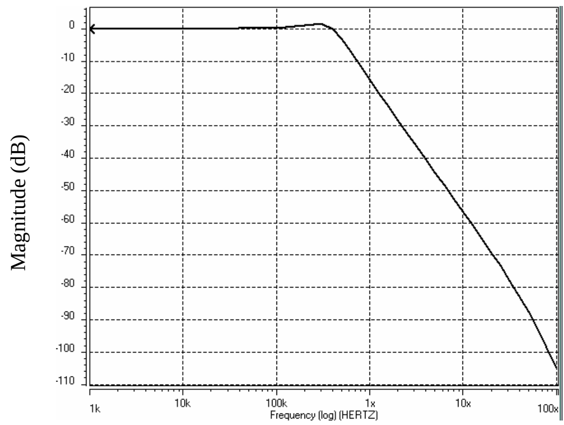

Fig. 3 Simulated lowpass response

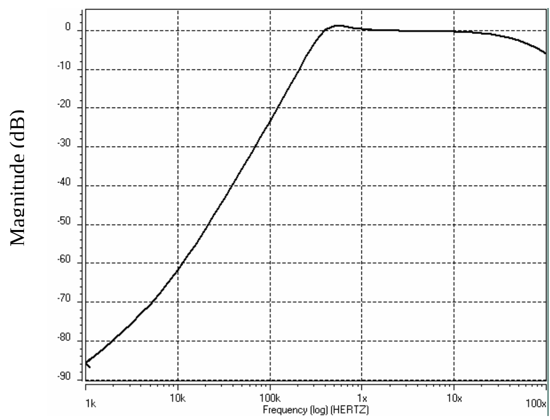

Fig. 4 Simulated highpass response

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