A Novel Multi-Input Single-Output Filter with Reduced Number of Passive Elements Using Single Current Conveyor

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***Abstract*-A new biquadratic universal filter configuration realizing second-order low-pass, band-pass, and high-pass fiters using single current conveyor is proposed. Using this configuration high-pass, low-pass and band-pass fiters can be realized with little modifications. The circuit employs a second-generation current conveyor (CCII+), and only four passive components. Since the current conveyor is a high performance active element, the circuit proposed is suitable for wide band applications. The derived filters can be easily cascaded and use reduced number of passive components compared to previously reported counterparts. To illustrate the design possibilities provided by the introduced circuit current mode multifunction filters are constructed and tested.**

I. INTRODUCTION

The interest in current-mode signal processing circuit is still growing [1-14]. Universal or multifunction filters are a useful class of current-mode as well as voltage-mode filters since they permit realisation of different filter functions with the same topology depending on the port used. They therefore bring versatility, simplicity and cost reduction to the integrated circuit manufacturer. The current-mode universal filters may be divided into subcategories considering the input and output ports. Some filters are single-input multiple-output type (SIMO) and others are multiple-input single-output (MISO) type. For both classes low input impedance and/or high output impedance is advantageous from cascadability point of view. For certain filters signal output is obtained on a passive element thus additional active elements will be needed for those filters to sense the output signal and to cascade [1-4]. For cascadability to obtain higher order filters the structure should exhibit high output resistance.

For the cases where power consumption is an important parameter, the number of active elements employed will be important. Some multiple output current-mode filters with fewer number of active elements realise two filter functions simultaneously [2].

This paper presents a universal filter employing only a single second generation current conveyor and is of MISO type. The filter exhibits high output impedance and is canonical in the number of capacitors and resistors. For the cascade implementations to obtain high-even-order filters the number of active elements will only be equal to $n/2$, where n is the order of the filter.

II. SECOND GENERATION CURRENT CONVEYOR

The second generation current conveyor CCII+ is illustrated in Fig.1. Its terminal relationship can be given as

$$V_X=V_Y \qquad I_Y=0 \qquad I_Z=I_X \tag{1}$$

III. PROPOSED FILTER TOPOLOGY

The general form of the universal filter topology proposed is illustrated in Fig. 2.

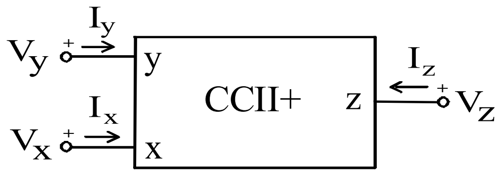

Fig. 1. Terminal voltages and currents of the second-generation current conveyor

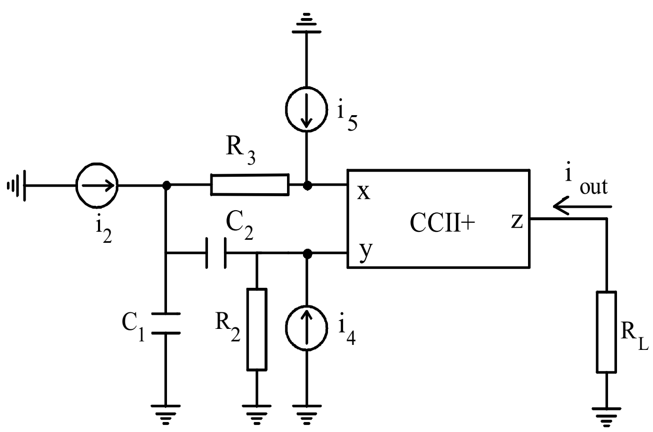

Fig. 2. Proposed filter topology

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Setting the currents $i_5 = i_4 = 0$ and applying an input current of i_2 to the circuit, a low-pass filter function is obtained which is described by

$$\frac{i_{out}}{i_2} = \frac{G_2 G_3}{s^2 C_1 C_2 + s(C_1 + C_2)G_2 + G_2 G_3} \tag{2}$$

Taking the currents $i_2 = i_5 = 0$ and applying an input current of i_4 to the circuit, a band-pass filter function is obtained. The BP transfer function is given by

$$\frac{i_{out}}{i_4} = \frac{sC_1 G_3}{s^2 C_1 C_2 + sG_2(C_1 + C_2) + G_2 G_3} \tag{3}$$

Providing the conditions

$$i_2 = -i_5 \tag{4}$$

and

$$i_4 = i_5 \frac{G_2(C_1 + C_2)}{G_3 C_1} \tag{5}$$

a high-pass filter is obtained. The HP transfer function is described by

$$\frac{i_{out}}{i_5} = \frac{s^2 C_1 C_2}{s^2 C_1 C_2 + sG_2(C_1 + C_2) + G_2 G_3} \tag{6}$$

The pole angular frequency and the quality factor of the filter are given by

$$\omega_o = \sqrt{\frac{G_2 G_3}{C_1 C_2}} \tag{7}$$

$$Q = \frac{1}{(C_1 + C_2)} \sqrt{\frac{C_1 C_2 G_3}{G_2}} \tag{8}$$

IV. Simulation Results and Discussion

To verify the above given theoretical analysis, multifunction filters realizing Butterworth characteristic with unity gain and a pole frequency of f_o ≅225kHz are designed using the proposed configuration of Fig.2 with passive element values R_2=0.5kΩ, R_3=1kΩ C_1=1nF, C_2=1nF for all type second-order filters. The active element used in this design is the commercially available CFOA AD844/AD of Analog Devices. The circuit was supplied with symmetrical voltages of V_{DD}=12V and V_{SS}=–12V.

Theoretical results and simulation results for the LP, BP and HP type filters are illustrated in Fig. 3. Theory and simulations are verified by measurement data. Measurements result in a pole-frequency of f_o= 224.8kHz. Theoretical filter characteristics are also given in Fig. 3 for comparison. The simulation data given in Fig. 3 agree quite well with the theoretical analysis. Furthermore, the large signal behaviour of the circuit is investigated by applying a 225 kHz input signal with an amplitude of 800μA and observing the dependence of the BP output voltage on the load resistance. The results are illustrated in Table 1. The output waveform obtained from the oscilloscope for a load resistance of R_L=10k and a 225 kHz input signal with an amplitude of 1000μA is illustrated in Fig. 4. It can be clearly seen from Fig. 4 that an output voltage of V_{OPP} = 20V is available even at a frequency of 225kHz.

TABLE 1
DEPENDENCE OF THE OUTPUT VOLTAGE ON THE LOAD RESISTANCE R_L FOR A 225 KHZ INPUT SIGNAL WITH AN AMPLITUDE OF 800μA

R_L (kΩ)	V_{op} (V)
0.5	0.44
1	0.85
2	1.65
3	2.5
4.3	3.6
4.7	4
6.2	5
7.5	6
10	8
13	10

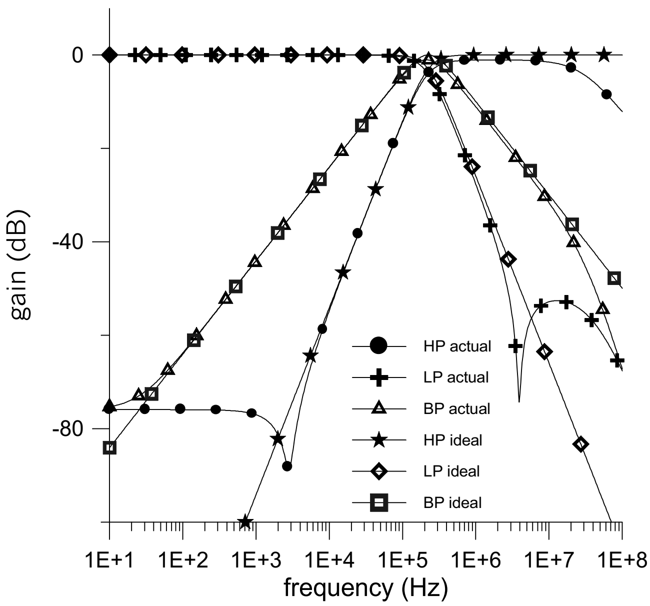

Fig. 3. Theoretical and simulated LP, BP and HP filter characteristics of the proposed filter in Fig. 2.

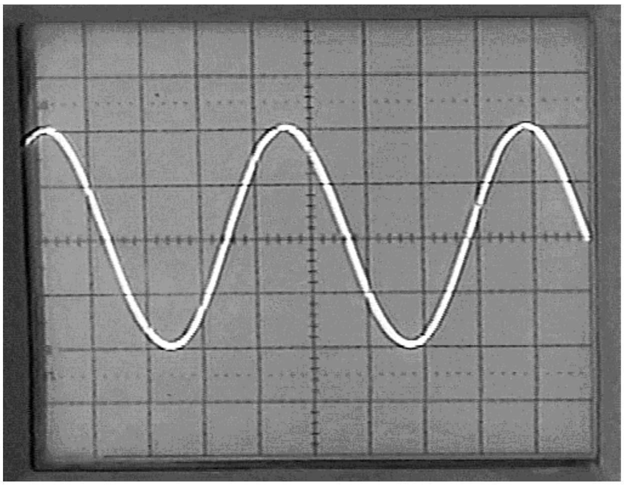

Fig. 4. Experimentally obtained output waveform of the filter illustrated in Fig. 2 obtained for a load resistance of R_L=10k and a 225 kHz input signal with an amplitude of 1000µA; vertical: 5V/div, horizontal: 1µs/div.

V. CONCLUSION

A current mode multi-input single-output multipurpose filter configuration is proposed using CCII+ or CFOA as active component, which is suitable for high performance analog signal processing. Note that the proposed filter uses reduced number of passive and a single active element, namely two resistors, two capacitors, as well as one CCII+ or CFOA. LP and BP filters do not require any matching condition, HP filter configuration does require a simple matching condition, which is quite important in mass production. The filters proposed are cascadable because of high impedance of output-terminal z which can be considered as a current source for the next stage. Moreover, the output signal is also available at the low impedance output of a voltage buffer if CFOA is used for realization of the proposed topology.

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