A Novel Multi-Function Inverse Active Filter using CFOAs

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Abstract— Inverse filters are widely used in various control, instrumentation and communication systems to correct the distortions of signals caused by signal processing or transmission systems. In this paper present a novel approach multi-function inverse biquad configuration based on current feedback operational amplifiers (CFOAs) and grounded passive elements. The proposed configuration is used to realize inverse lowpass, inverse bandpass and inverse highpass filter functions. The relevant coefficients of the inverse filters are orthogonal adjustable by independent passive elements. All the passive elements in the proposed configuration are grounded to benefit easier electronic tunability.

Key words: Inverse active filters, Current feedback operational amplifier, Analog signal processing, Current-mode filters, voltage-mode filters, multifunction inverse active filter

I. INTRODUCTION

In communication as well as in control and instrumentation systems, there are numerous situations in which an electrical signal is changed through a linear or nonlinear transformation by a processing or a transmission system. Presently some methods have dealt with this task of inverse-filtering [1-8]. There are other configurations have dealt with general techniques of generating inverse transfer functions [1, 2]. In A. Leuciuc el [3], a general approach is presented for obtaining the inverse transfer function for linear dynamic systems and the inverse transfer characteristic for non-linear resistive circuits. In B. Chipipop el [5], a procedure for deriving current-mode, four-terminal floating nullor (FTFN)-based inverse filter from the voltage-mode filter is given. It uses the method in [3] and dual transformation [9] during the procedure. Due to the use of dual transformation, this approach can only be applied to planar circuit. By the use of ad joint transformation, another easier procedure for deriving current-mode FTFN-based inverse filter from the voltage-mode filter is presented and it is applicable to nonplanar circuits [6]. All the proposed approaches in [3, 5, and 6] are useful for obtaining single-input single-output inverse filters. The new inverse active filter configurations presented in [8] utilized three CFOAs, two grounded capacitors and three or more resistors. In this paper, we present a novel multifunction inverse active filter scheme based on CFOAs and grounded passive elements. By slight modification of the passive elements of the proposed scheme, various in-verse filter functions can be realized. The workability of the proposed scheme is verified by P-SPICE simulations.

II. THE PROPOSED CONFIGURATION

The current-feedback operational amplifier, such as AD844 from Analog Devices Inc. [10], has been used as a building block in circuit design. The advantages of CFOAs are their constant bandwidths, independent closed-loop gains and high slew-rate capabilities. The CFOA can be described using the following matrix-relations:

$$\begin{bmatrix} v_x \\ i_y \\ i_z \\ v_w \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} i_x \\ v_y \\ v_z \\ i_w \end{bmatrix} \tag{1}$$

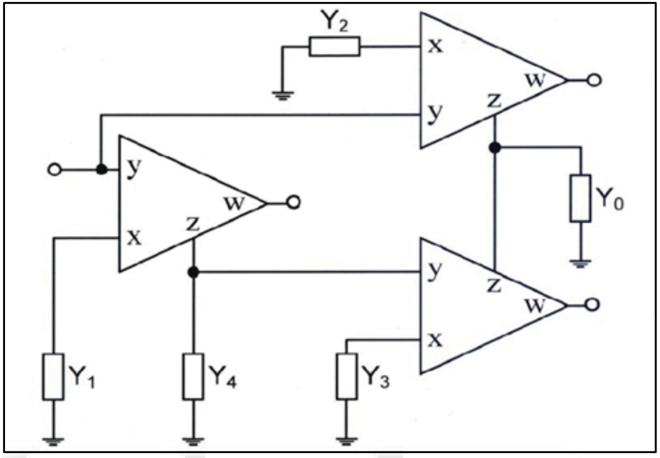


Fig. 1: The proposed inverse filter configuration

A routine analysis of the configurations of Fig.1 yields the transfer functions given below

$$\frac{V_{01}}{V_{in}} = \frac{V_{03}}{V_{in}} = \frac{y_1 y_3 + y_2 y_4}{y_0 y_4} \tag{2}$$

$$\frac{V_{02}}{V_{in}} = \frac{y_1}{y_4} \tag{3}$$

If the admittances are $y_0 = G_0, y_1 = sC_1, y_2 = sC_2 + G_2, y_3 = sC_3$ and $y_4 = G_4$, the functions of inverse lowpass filter and inverse integrator can realized at $V_{01}$and V_{02} respectively. These are given by,

$$\frac{V_{01}}{V_{in}} = \frac{V_{03}}{V_{in}} = \frac{s^2 C_1 C_3 + sC_2 G_4 + G_2 G_4}{G_0 G_4} \tag{4}$$

$$\frac{V_{02}}{V_{in}} = \frac{sC_1}{G_4} \tag{5}$$

From equation (4), the values of C_1,C_2,G_0 and G_2 are tunable, so that system parameters of inverse filter, such as corner frequency and quality factor are independently adjusted by the passive elements.

In equation (2), if the admittances are $y_0 = sC_0, y_1 = sC_1, y_2 = sC_2 + G_2, y_3 = sC_3$ and $y_4 = G_4$, the functions of inverse bandpass filter and inverse integrator can be realized at $V_{01}$and V_{02}, respectively. They are given by,

$$\frac{V_{01}}{V_{in}} = \frac{V_{03}}{V_{in}} = \frac{s^2 C_1 C_3 + sC_2 G_4 + G_2 G_4}{sC_0 G_4} \tag{6}$$

$$\frac{V_{02}}{V_{in}} = \frac{sC_1}{G_4} \tag{7}$$

Similarly, if the admittances are $y_0 = sC_0, y_1 = G_1$,$y_2 = sC_2 + G_2, y_3 = G_3$ and $y_4 = sC_4$, the functions of inverse highpass filter and inverse differentiator can be realized at $V_{01}$and V_{02}, respectively. They are given by,

$$\frac{V_{01}}{V_{in}} = \frac{V_{03}}{V_{in}} = \frac{s^2C_2C_4 + sC_4G_2 + G_1G_3}{s^2C_0C_4} \qquad (8)$$

$$\frac{V_{02}}{V_{in}} = \frac{G_1}{sC_4} \qquad (9)$$

The output $V_{03}$is same as V_{01}, this provides more flexibility in filter applications.

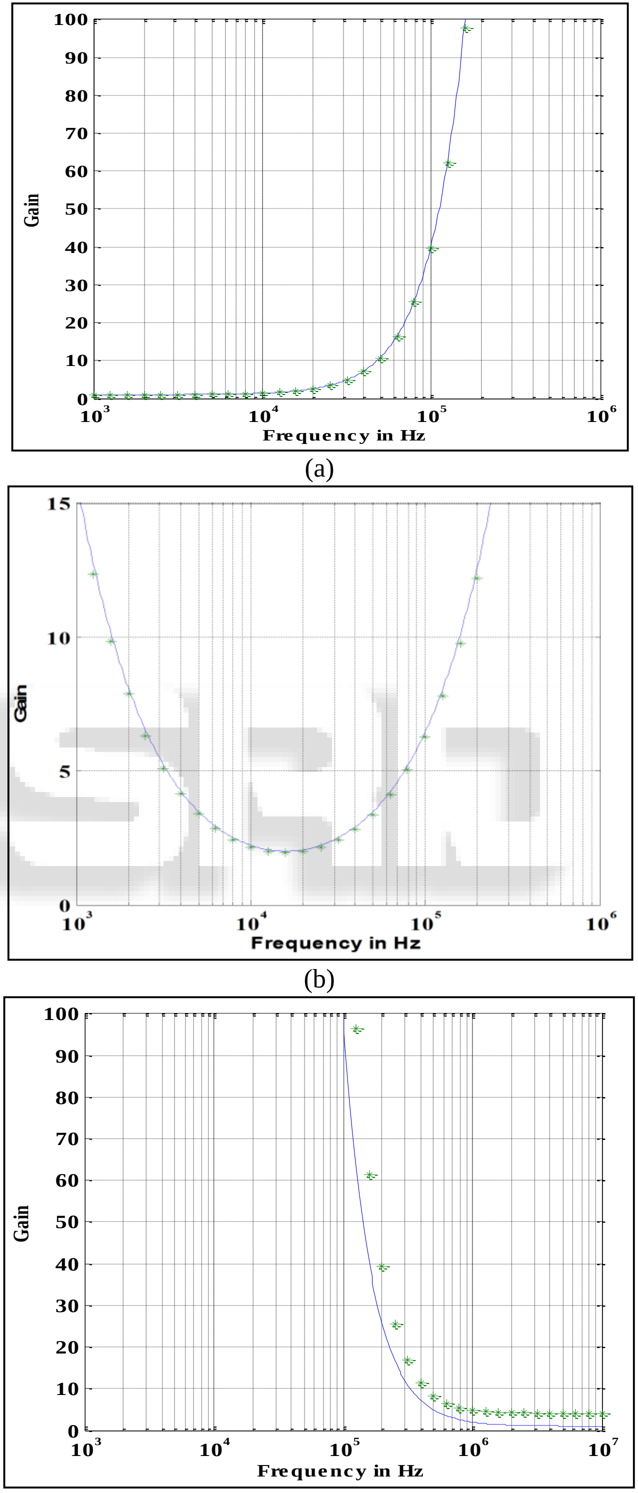
From the equations (2) and (3), we can derive all the filter functions as shown in Table 1 using six passive elements. The presented scheme in Fig.1 provides more flexible functions and different realization with identical configuration.

Case	Function at $V01$	Function at $V02$	$y0$	y_1	y_2	y_3	y_4
1	Inverse lowpass	Differential	G_0	sC_1	$sC_2 + G_2$	sC_3	G_4
2	Inverse lowpass	Inverse lowpass	G_0	$sC_1 + G_1$	G_2	sC_3	G_4
3	Inverse lowpass	Differential	G_0	sC_1	G_2	$sC_3 + G_3$	G_4
4	Inverse bandpass	Differential	sC_0	sC_1	$sC_2 + G_2$	sC_3	G_4
5	Inverse bandpass	Inverse lowpass	sC_0	$sC_1 + G_1$	G_2	sC_3	G_4
6	Inverse bandpass	Differential	sC_0	sC_1	G_2	$sC_3 + G_3$	G_4
7	Inverse bandpass	Integration	G_0	G_1	$sC_2 + G_2$	G_3	sG_4
8	Inverse bandpass	Integration	G_0	G_1	sC_2	$sC_3 + G_3$	sG_4
9	Inverse bandpass	Inverse highpass	G_0	$sC_1 + G_1$	sC_2	G_3	sG_4
10	Inverse highpass	Integration	sC_0	G_1	sC_2	$sC_3 + G_3$	sG_4
11	Inverse highpass	Inverse highpass	sC_0	$sC_1 + G_1$	sC_2	G_3	sG_4
12	Inverse highpass	Integration	sC_0	G_1	$sC_2 + G_2$	G_3	sG_4

Table 1: All The Inverse Filter Functions Using Six Passive Elements

III. SIMULATION RESULTS

To verify the workability of the proposed new configuration, the circuit has been tested on PSpice using AD844 type CFOA's library file. The theoretical and simulated plots of frequency responses are shown in Fig.2 which is found to be in good agreement. These results, thus, confirm the workability of the proposed new configuration. In simulation, the values of all resistors and all capacitors are 10kΩ and 1nF respectively. The typical frequency responses of inverse lowpass (the case 1 of Table 1), inverse bandpass (the case 4 of Table 1) and inverse highpass (the case 12 of Table 1) are shown in Fig.2



(a)

(b)

Fig. 2: Typical frequency responses of proposed new configuration: (a) inverse lowpass filter, (b) inverse bandpass filter, and (c) inverse highpass filter

IV. CONCLUSION

We have proposed a novel configuration for the realization of multifunction inverse filter. It consists of CFOAs and grounded passive elements. The various inverse filter functions are realized by slight modifications of passive elements. It offers more flexibility in filter applications. The workability of these configurations has been confirmed by simulation results

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