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Fractional Order Inverse Filters using Current Feedback Operational Amplifiers and its application in Bio-medical Instrumentation

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ABSTRACT:

In this paper, current feedback operational amplifiers (CFOAs)-based fractional order inverse filter is proposed. A new configuration of fractional order inverse filters (FOIF) is presented to realize inverse low pass, high pass and band pass filters in fractional order domain. The proposed configuration of fractional order inverse filters has been simulated in PSPICE using AD844 type CFOAs to validate the theoretical propositions. It's utilized to remove the artifacts present in biomedical signal.

Keywords: Analog signal processing, Fractional order inverse filter, Current feedback operational amplifier.

INTRODUCTION:

Recently, fractional order analog signal processing and signal generation circuits ([1]-[28] and the references cited therein) have received growing interest. Consequently, this has become an interesting research area, due to its inter-disciplinary applications in the field of science and engineering such as in biomedical [1]-[3], control systems [4]-[6], analog filters [7]-[20] and oscillators [21]-[26]. Due to its design flexibility and controllability because of additional degree of freedom by the fractional order parameter [20], the fractional order filters have become an important part of the analog signal processing. Inverse filters are employed in various applications in communication, instrumentation and control systems, where these filters are required to correct the distortions of the signal caused by signal processors or transmission systems [29].

A number of new configurations that realize inverse filters employing active building blocks have been proposed by many researchers in the open literature. A brief account of the earlier work done in this area is as follows:

In [29]-[30], a nullor-based approach to realize inverse filters was proposed. A four terminal floating nullor (FTFN)-based inverse filters were reported in [31]-[32]. On the other hand, the current feedback operational amplifiers (CFOAs) have been used to realize inverse filters in [33]-[36], while current differencing buffered amplifier (CDBA) was used in [35] for the realization of universal inverse filters. In [38] and [39], a current differencing transconductance amplifier (CDTA) was employed to realize inverse filters, while second generation current conveyors (CCIIs) were used in [40] to realize all pass filter and its inverse version. In [41], another building block named as differential difference current conveyor (DDCC) was used to realize inverse filters, whereas modified CFOA-based inverse filters were proposed in [42]. The multi output operational transconductance amplifiers (OTAs) were used to realize inverse filters operating in both current mode and

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voltage mode in [43] and operational transresistance amplifiers (OTRAs) based inverse filters have been proposed in [44]. First fractional *order inverse filter* was proposed by Bhaskar, Kumar and Kumar using OPAMP [45]. Therefore, the purpose of this article is to propose new CFOAs based generalized universal fractional order inverse filter configurations, which can realize fractional order low pass, band pass and high pass filters from the same configuration as special cases. The workability of the proposed fractional order inverse filters has been established by SPICE simulations using AD844 type CFOA and sample results have been presented.

THE PROPOSED MULTIFUNCTION FRACTIONAL ORDER INVERSE FILTER STRUCTURES:

The proposed generalized structure of fractional order inverse filter is shown in Fig. 1.

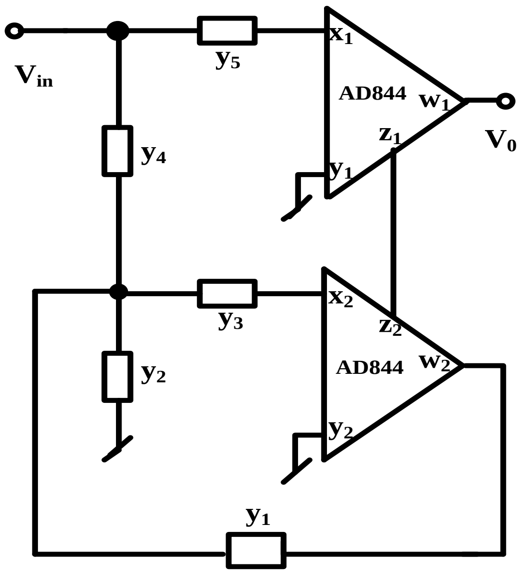

Figure 1. Proposed generalized fractional order inverse active filter structure

Considering an ideal CFOA, it's characterized by $I_y = 0$, $V_x = V_y$, $I_z = I_x$, and $V_w = V_z$. Through straight forward analysis of circuit shown in fig.1 the transfer function can be written as :

$$\frac{V_0}{V_{in}} = -\frac{y_3 y_4 + y_5 (y_1 + y_2 + y_3 + y_4)}{y_1 y_3} \qquad (1)$$

where y_i , i = 1-5 are the admittances.

From equation (1), the various inverse filters can be obtained by appropriate choice (s) of admittances as follows:

(i) Fractional order inverse low pass filter: If we choose $y_2 = s^{\alpha} C_2$, $y_5 = s^{\alpha} C_5$, $y_1 = \frac{1}{R_1}$, $y_3 = \frac{1}{R_3}$ and $y_4 = \frac{1}{R_4}$, the resulting transfer function becomes

(2)

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$$\frac{V_0(s)}{V_{in}(s)} = -\frac{1}{\dfrac{\left(\dfrac{1}{C_2C_5R_1R_3}\right)}{s^{2\alpha} + \dfrac{s^{\alpha}}{C_2}\left\{\dfrac{1}{R_1} + \dfrac{1}{R_3} + \dfrac{1}{R_4}\right\} + \dfrac{1}{C_2C_5R_3R_4}}} \tag{2}$$

(ii) Fractional order inverse band pass filter: If we choose

$y_3 = s^{\alpha}C_3, y_4 = s^{\alpha}C_4, y_1 = \dfrac{1}{R_1}, y_2 = \dfrac{1}{R_2}$ an $y_5 = \dfrac{1}{R_5}$, the resulting transfer function becomes

$$\frac{V_0(s)}{V_{in}(s)} = -\frac{1}{\dfrac{\left(\dfrac{s^{\alpha}}{R_1C_4}\right)}{s^{2\alpha} + \dfrac{s^{\alpha}}{R_5}\left\{\dfrac{1}{C_3} + \dfrac{1}{C_4}\right\} + \dfrac{1}{R_5C_3C_4}\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)}} \tag{3}$$

(3)

(iii) Fractional order inverse high pass filter: If we choose

$y_1 = s^{\alpha}C_1, y_3 = s^{\alpha}C_3, y_4 = s^{\alpha}C_4\ y_2 = \dfrac{1}{R_2}$ and $y_5 = \dfrac{1}{R_5}$, the resulting transfer function becomes

$$\frac{V_0(s)}{V_{in}(s)} = -\frac{1}{\dfrac{\left(\dfrac{C_1 s^{2\alpha}}{C_4}\right)}{s^{2\alpha} + \dfrac{s^{\alpha}}{R_5C_3C_4}\{C_1 + C_3 + C_4\} + \dfrac{1}{C_3C_4R_2R_5}}} \tag{4}$$

(4)

PSPICE AND MATLAB SIMULATION RESULTS OF PROPOSED FRACTIONAL ORDER INVERSE FILTERS:

The PSPICE and MATLAB simulations were performed on proposed fractional order inverse active filters. Fractional order capacitors [45] of order 0.9 and 0.8 used in PSPICE simulation. The fractional order inverse filters were designed to have a ω_h or ω_m of 1kHz for $\alpha = 1$ for FOILP, FOIHP FOIBP filter. The component values used to design fractional order inverse active filters are provided in Table 1.

Table 1 Component values used in the design of fractional order inverse active filters

FOILP	FOIHP	FOIBP
$R_1 = 1060\Omega$	$R_2 = 754.3\Omega$	$R_1 = 1280\Omega$
$R_3 = 530\Omega$	$R_5 = 3395.3\Omega$	$R_2 = 3865.6\Omega$
$R_4 = 1060\Omega$	$C_1 = 0.0995\ \mu F/sec^{(\alpha-1)}$	$R_5 = 2560\Omega$
$C_2 = 0.382\ \mu F/sec^{(\alpha-1)}$	$C_3 = 0.0995\ \mu F/sec^{(\alpha-1)}$	$C_3 = 0.0995\ \mu F/sec^{(\alpha-1)}$
$C_5 = 0.0955\ \mu F/sec^{(\alpha-1)}$	$C_4 = 0.0995\ \mu F/sec^{(\alpha-1)}$	$C_4 = 0.0995\ \mu F/sec^{(\alpha-1)}$

The PSPICE and MATLAB simulation results of new proposed fractional order inverse active filters and integer order inverse filters of Fig. 1 are shown in Fig. 2.

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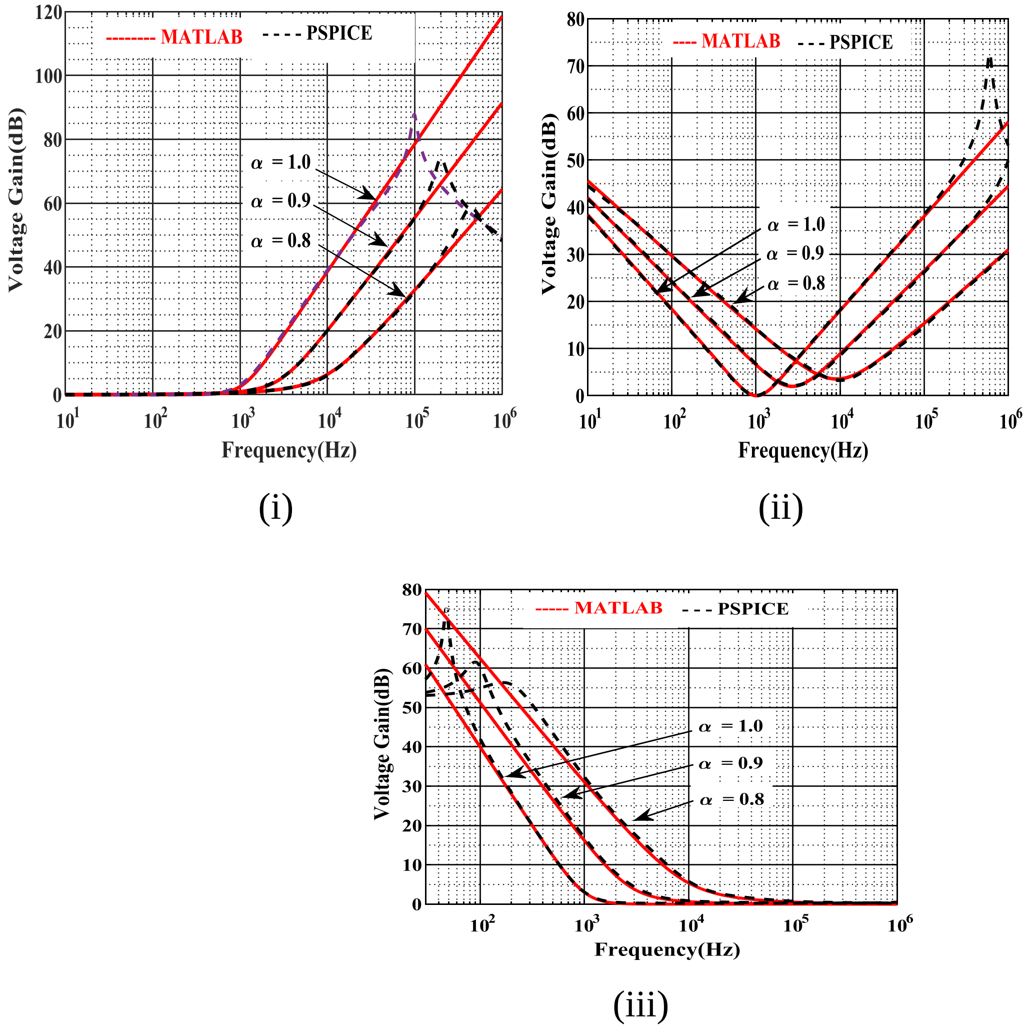

Figure 2 Frequency responses of FOIFs of Fig. 1 (i) FOILP (ii) FOIBP (iii) FOIHP

The comparative results of frequency of proposed fractional order inverse active filters along with integer order counterparts are shown in Table 2. The stop band attenuations are given in Table 3.

Table 2 Half power frequency and minimum frequency (in Hz) of proposed FOIFs of Fig. 3.16

Order	FOILP		FOIHP		FOIBP	
	PSPICE	MATLAB	PSPICE	MATLAB	PSPICE	MATLAB
2.0	1000	1065	977	1000	1000	1008
1.8	2089	2163	3715	3455	2727	2818
1.6	5248	5144	16600	16630	9772	9193

Table 3 Stop band attenuation (dB/decades) of proposed inverse filters of Fig. 3.16

Order	FOILP		FOIHP		FOIBP	
	PSPICE	MATLAB	PSPICE	MATLAB	PSPICE	MATLAB

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2.0	37.40	39.99	39.50	40.36	20.27	20.03
1.8	35.30	35.65	35.56	36.26	17.58	17.50
1.6	31.20	31.50	29.22	31.06	15.40	15.56

From Table 2 and Table 3, it is noted that the PSPICE and MATLAB simulation results of proposed FOIFs are in good agreement.

Application of proposed Fractional order inverse filter in design of biomedical instrument: Bio-medical instrument is used to acquire the biomedical signal such as ECG, EEG and others. While acquiring the signals, other unwanted signals of different frequency are mixed in original biomedical signal. Therefore fractional order inverse filter is used to remove the unwanted signals (low frequency/high frequency) from biomedical signal.

CONCLUSIONS:

Through this paper, a new multifunction *fractional order inverse filter structure* is proposed, which can realize the fractional order inverse low pass, high pass and band pass filters using two CFOAs. Comparative results of the fractional order inverse filters with its integer order counterparts are shown in Tables. The extra degree of freedom provided by the fractional order parameter adds more control on filter parameters like cutoff frequency and slope of stop band attenuation. The workability of the proposed structures has been demonstrated by PSPICE simulation results. Proposed fractional order inverse filters are also used to remove the artifacts (unwanted signal of various frequencies) from bio-medical signal.

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