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A Novel Current-Mode Multifunction Inverse Filter using Single CFA

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Abstract: ***A novel current-mode multifunction inverse filter configuration using single current feedback amplifier (CFA) is presented. The proposed filter employs only one CFA and few passive components. The proposed circuit realizes inverse lowpass, inverse bandpass and inverse highpass filter functions with proper admittances. The characteristics of proposed multifunction inverse filter configuration are- current-mode realization; use of only one CFA; use of grounded passive components except one virtually grounded and realizing all three basic inverse filters. The proposed current-mode inverse filter circuit has been tested by TINA PRO simulation program and results justified the theoretical analysis.***

Keywords: ***Current Feedback Amplifier, Current-mode, Voltage Mode, Multifunction, Inverse Filter, Admittances.***

I. INTRODUCTION

This design of analog inverse filter is useful in communication, control and instrumentation engineering. The inverse filters are used to reverse the distortion of signal incurred due to signal processing and transmission. The distorted signal is to be converted to the input signal. The inverse filtering is a technique to inverse the transfer characteristic of the original signal [1, 2]. In digital signal processing, various techniques are used to realize digital inverse filters [2]. However, few circuits are reported in literature for realization of analog inverse filters [3, 15-32].
Most of the inverse filter circuits reported in literature are voltage–mode circuit. The voltage mode inverse filters are realized mostly by current feedback amplifier (CFAs), current conveyor (CCIIs),current differencing buffered amplifier (CDBAs), operational trans resistance amplifier (OTRA) and operational transconductance amplifier (OTAs) [18,19,21,22,24,26-32]. The current-mode technique has several advantages such as higher bandwidth, large dynamic range, low power consumption, greater linearity and simpler circuitry. The current feedback amplifiers have found wide application in the design of active filters and oscillators due to several advantages like high slew rate, constant bandwidth and also commercially available [4-14].

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The inverse filters in current-mode have been realized using four terminal floating nullors (FTFNs) [15-17], current differencing transconductance amplifier (CDTA) [20] and current differencing buffered amplifier (CDBA) [23] respectively. There are many reports by several researchers on analog inverse filters. In [3], a general method has been proposed for realizing inverse filter using nullors. Chipipop and Surakampontorn [15] gave procedure for current-mode four terminal floating nullor (FTFN) based inverse filter from voltage mode inverse filter. Wang and Lee [16] proposed current-mode inverse filters using FTFNs. Abuelmatti [17] employed one FTFN to obtain current-mode inverse lowpass, highpass and bandpass filters. A voltage mode inverse filter was implemented using current feedback operational amplifiers (CFOA) which realize inverse lowpass, bandpass, and highpass and bandreject filter configurations [18]. A voltage mode inverse multifunction filter using three CFOAs and passive components was proposed [19]. Shah, Quadri and Iqbal [20] proposed inverse all pass filter using current differencing transconductance amplifier (CDTA). A current conveyor (CCII) based inverse filter was realized [21]. Pandey, Pandey, Negi and Garg [22] presented voltage mode inverse filters using two current differencing buffered amplifiers (CDBAs). Nasir and Ahmad [23] proposed current-mode multifunction inverse filter using CDBA which realizes inverse lowpass, high pass and band pass filters. An inverse filter realized using DDCCs and minimum passive components [24]. Three modified current feedback operational amplifiers (MOCFOA) and five admittances are employed to obtain inverse lowpass, bandpass and highpass filters [25]. Tsukutani, Sumi and Yabuki [26] realized inverse lowpass highpass and bandpass filters using five or six multiple output operational transconductance amplifiers (MOTA). Patil and Sharma [27] used two CFOAs to obtain inverse filter. A multifunction inverse filter was presented using three current conveyors (CCII) and four or five admittances [28]. Singh, Gupta and Senani proposed operational transresistance amplifiers (OTRA) based inverse low pass, high pass and bandpass filters in voltage mode [29]. Pradhan and Sharma realized OTRA based inverse all pass and inverse band reject filters [30]. A multifunction inverse filter was reported using two CDBAs and passive components [31]. A voltage-mode analog inverse filter using three OTAs and two fractional capacitors (FCs) realized fractional inverse filters [32].
The review of the reported works in literature reveals that no inverse filter in current-mode employing a single CFA has been presented. Therefore, the main objective of this paper is to propose a novel current-mode multifunction inverse filter using only one CFA and five admittances.

By proper selection of admittances, inverse lowpass, inverse bandpass and inverse highpass filter functions can be realized from the same configuration. The use of one CFA is new to available inverse filter circuits. The simulation results are in agreement with theoretical analysis. A comparative analysis of inverse filters is given in Table-1. It is noted that the proposed circuit is using single CFA

II. CIRCUIT DESCRIPTION

The symbol of CFA circuit has been shown in Fig.1. The port relations of a CFA can be characterized by the following Eq. (1):

$$V_X = V_Y,\quad I_X = I_Z,\quad I_Y = 0 \quad \text{and } V_Z = V_O \qquad (1)$$

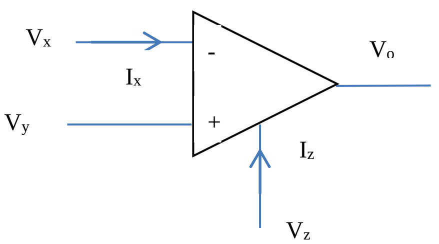

Fig.1. Circuit symbol of CFA

The current-mode multifunction inverse filter proposed circuit is shown in Fig. 2. The routine analysis of circuit yields the current transfer functions as follows:

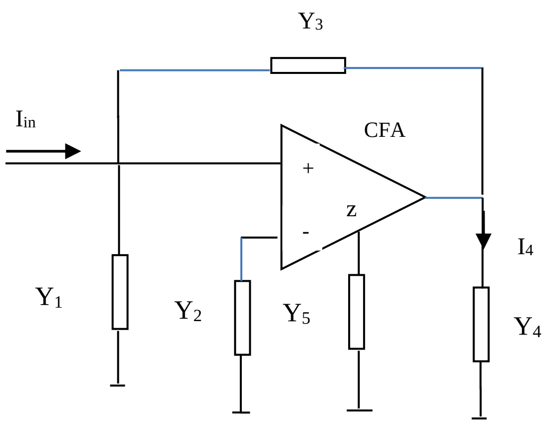

Fig. 2. Proposed circuit of CM inverse filter

$$\frac{I_4}{I_{in}} = \frac{N(s)}{D(s)} = \frac{Y_2Y_4}{Y_1Y_5 + Y_3Y_5 - Y_2Y_3} \qquad (2)$$

where

$$N(s) = Y_2Y_4$$

$$D(s) = Y_1Y_5 + Y_3Y_5 - Y_2Y_3$$

If admittances chosen are $Y_2 = sC_2 + G_2$,and

$Y_4 = sC_4 + G_4$, then

$$N(s) = (sC_2 + G_2)(sC_4 + G_4)$$

$$N(s) = S^2C_2C_4 + s(C_2G_4 + C_4G_2) + G_2G_4 \qquad (3)$$

The transfer function of inverse lowpass (ILP) filter can be obtained by choosing the admittances as $Y_1 = G_1, Y_2 = sC_2 + G_2, Y_3 = 0, Y_4 = sC_4 + G_4, Y_5 = G_5$. The resulting function of inverse lowpass filter is given by Eq. (4):

$$\frac{I_4}{I_{in}} = \frac{1}{G_1G_5/(s^2C_2C_4 + s(C_2G_4 + C_4G_2) + G_2G_4)} \qquad (4)$$

The transfer function of inverse highpass (IHP) filter can be obtained by choosing the admittances as $Y_1 = sC_1$, $Y_2 = sC_2 + G_2$, $Y_3 = 0$, $Y_4 = sC_4 + G_4$, $Y_5 = sC_5$. The resulting function of inverse highpass filter is given by Eq. (5):

$$\frac{I_4}{I_{in}} = \frac{1}{s^2C_1C_5/(s^2C_2C_4 + s(C_2G_4 + C_4G_2) + G_2G_4)} \qquad (5)$$

The transfer function of inverse highpass (IHP) filter can be obtained by choosing the admittances as $Y_1 = sC_1$, $Y_2 = sC_2 + G_2$, $Y_3 = 0$, $Y_4 = sC_4 + G_4$, $Y_5 = sC_5$. The resulting function of inverse highpass filter is given by Eq. (5):

$$\frac{I_4}{I_{in}} = \frac{1}{s^2C_1C_5/(s^2C_2C_4 + s(C_2G_4 + C_4G_2) + G_2G_4)} \qquad (5)$$

Similarly, the transfer function of inverse bandpass (IBP) filter can be obtained by choosing the admittances as $Y_1 = sC_1$, $Y_2 = sC_2 + G_2$, $Y_3 = 0$, $Y_4 = sC_4 + G_4, Y_5 = G_5$. The resulting function of inverse bandpass filter is given by Eq. (6):

$$\frac{I_4}{I_{in}} = \frac{1}{sC_1G_5/(s^2C_2C_4 + s(C_2G_4 + C_4G_2) + G_2G_4)} \qquad (6)$$

The natural angular frequency (ω_o) and the pole (Q) of the filter is:

$$\omega_o = \sqrt{\frac{G_2G_4}{C_2C_4}} \qquad (7)$$

$$Q = \frac{\sqrt{C_2C_4G_2G_4}}{(C_2G_4 + C_4G_2)} \qquad (8)$$

The gain constants of ILP, IHP and IBP responses are given by:

$$H_{ILP} = \frac{G_1G_5}{G_2G_4}$$

$$H_{IHP} = \frac{C_1C_5}{C_2C_4}$$

$$H_{IBP} = \frac{C_1G_5}{C_2G_4 + C_4G_2}$$

Table-I Comparison of proposed inverse filter with previously reported work

No. of Active Elem.	No. of Passive Elem.	Mode	No. of filter realized	Ref.
1Nullor	2-C,4-R	VM	IHP	[3]
1 FTFN	2-C,5-R	CM	ILP	[15]
1 FTFN	2-C,4-R	CM	IAP	[16]
1 FTFN	3-C,4-R	CM	ILP, IHP, IBP, IBR, IAP	[17]
3 CFA	2-C,5-R	VM	ILP, IHP, IBP, IBR	[18]

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3 CFA	3-C,3-R	VM	ILP, IHP, IBP	[19]
1 DTA	1-C,1-R	CM	IAP	[20]
1 CCII	1-C,,2-R	VM	IAP	[21]
2 CDBA	4-C,2-R	VM	ILP, IHP, IBP, IBR, IAP	[22]
2 CDBA	3-C,3-R	CM	ILP, IHP, IBP	[23]
3 DDCC	2-C,2-R	VM	ILP, IBP, IHP	[24]
3 CFA	4-C,3-R	VM	ILP, IBP, IHP	[25]
12 OTAs	2-C	VM-CM	ILP, IHP, IBP	[26]
2 CFA	2-C,6-R	VM	ILP, IHP, IBP, IBR	[27]
3 CCII	4-5C,5-R	VM	IHP, IBP,ILP	[28]
2 OTRA	3-C,4-R	VM	ILP, IHP, IBP	[29]
2OTRA	4-C,5-R	VM	IAP,IBR	[30]
2CDBA	3-C,4-R	VM	ILP, IHP, IBP	[31]
3OTA	2-C	VM	ILP, IHP, IBP	[32]
1 CFA	4-C,4-R	CM	ILP, IHP, IBP	Proposed

III. NON-EQUIVALENT CIRCUITOF CFA

Fig.3. shows the non-ideal equivalent circuit model of the CFA. R_x is the input resistance of the x-terminal, R_y // $(1/sC_y)$ represents the y-terminal parasitic input impedance, R_p // $(1/sC_p)$ at the compensation terminal z [7]. The values of the various parasitics for the bipolar CFAs (AD844) are R_x=50Ω, C_p=5.5pF, R_p= 3MΩ, R_y=2MΩ and C_y=2pF.

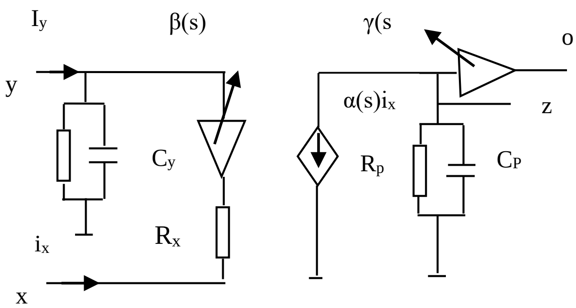


Fig.3. Non-ideal equivalent circuit of the CFA includes the parasitic impedances

IV. SENSITIVITY ANALYSIS

Taking into account the tracking errors of current feedback amplifier, the terminal equation (1) get modified as equation (9):

$$I_z = \alpha I_x,\quad V_x = \beta V_y\ ,\ \text{and}\ \ V_O = \gamma V_z \qquad (9)$$

where $\alpha = 1 - \varepsilon_1(|\varepsilon_1| <<1)$ denotes the current tracking error, $\beta = 1 - \varepsilon_2(|\varepsilon_2| <<1)$ is the input voltage tracking error and $\gamma = 1 - \varepsilon_3(|\varepsilon_3| << 1)$ is the output voltage tracking error of the current feedback amplifier.

Ry

The passive sensitivities of ω_o and Q for the proposed current-mode inverse filter can be expressed as:

$$S_{G_2}^{\omega o} = S_{G_4}^{\omega o} = -S_{C_2}^{\omega o} = -S_{C_4}^{\omega o} = \frac{1}{2}$$

$$S_{G_2}^{Q} = S_{C_4}^{Q} = \frac{1}{2} - \frac{C_4 G_2}{C_4 G_2 + C_2 G_4}$$

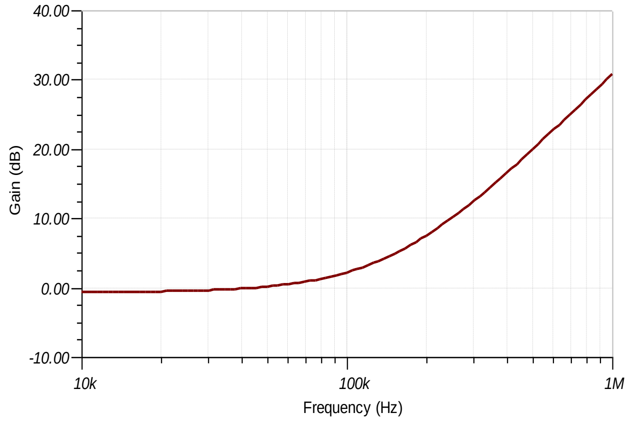
$$S_{G_4}^{Q} = S_{C_2}^{Q} = \frac{1}{2} - \frac{C_2 G_4}{C_4 G_2 + C_2 G_4}$$

It is observed that the passive sensitivities are less than unity in magnitude. Hence, the performances of proposed current-mode inverse filters are not affected.

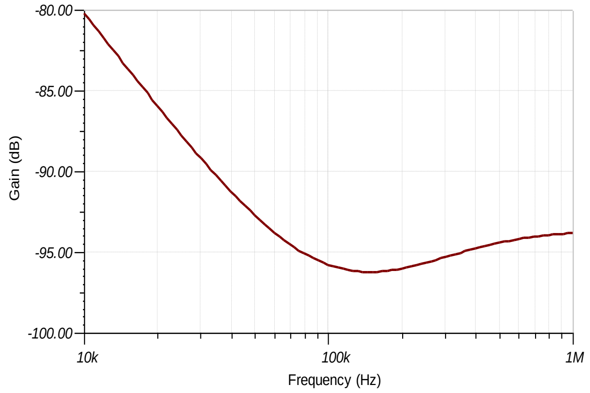
V. SIMULATION RESULT

The proposed current-mode inverse filter has been simulated with TINA PRO software. The inverse filter has been designed for f_O =796.18 KHz and Q = 1.

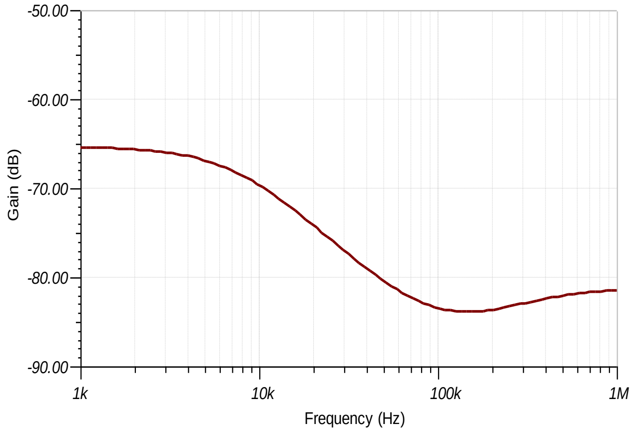
The CFA has been realized with available IC AD 844. The equal values of passive components are used. The supply voltages are ±12V. All the resistors are taken as 10KΩ and capacitors as 20pF. The simulated frequency characteristics for inverse lowpass, inverse bandpass and inverse highpass filter functions are shown in Fig.4. The simulation results agree well with theoretical analysis of the inverse filter.



(a) Inverse Lowpass Filter



(b) Inverse Bandpass Filter



(c) Inverse Highpass Filter

Fig.4. Frequency Response of Inverse Filters

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VI. CONCLUSIONS

A novel current-mode multifunction inverse filter using one CFA has been presented. The proposed circuit uses one CFA and five admittances. The inverse lowpass, inverse bandpass and inverse highpass filter functions are realized by proper selection of admittances. The proposed inverse filters have the advantages of using only one CFAand all grounded passive components except one virtually grounded. The simulation results are in agreement with theoretical analysis. The use of single CFA is a new configuration to inverse filter circuits available in literature.

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