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Single CDBA Realization of Inverse Filters

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Abstract - *A new single CDBA configuration is introduced, which can realize all the five generic inverse filters. Capacitors are either actually grounded or virtually grounded.*

Keywords - *CDBA, inverse filter functions, inverse low pass filter, inverse high pass filter, inverse bandpass filter, inverse band-reject filter, inverse all-pass filter.*

I. INTRODUCTION

Inverse filters that have an inverse transfer function of the original system are needed for correcting electrical signal distortions caused by the transmission system or signal processors. They are used in control systems, communication, and instrumentation [1,2]. Though there are several techniques for obtaining inverse *digital* filtering, only a few circuits are known for realizing continuous-time analog inverse filters.

A single four-terminal floating nullor-based inverse filter has been reported [1][2][3]. Wang and Lee [1] realize only all-pass filters. Chipipop and Surakampontorn [2] realize only a low pass filter. Abuelma'atti [3] realizes all the five inverse filters. All these use floating capacitors.

Using multiple current feedback operational amplifiers as an active building block, few inverse active filters [4-7] have been reported. Patil and Sharma [7] use a floating capacitor and a large number of resistors. Herencsar et al. [8] realize inverse low pass (ILP), inverse high pass (IHP), and inverse bandpass (IBP) and require multiple differential-difference, current conveyors. Tsukutani et al. [9] realize these filters using multiple operational transconductance amplifiers.

The inverse filter circuits [10]-[15] use more than one active device: second-generation current conveyors [10,11], voltage differencing trans-conductance amplifiers, and operational trans-resistance amplifiers [13-15].

An active block, namely the current buffered differencing amplifier (CDBA), has been presented by Acar and Ozoguz [22]. It can be operated in several megahertz frequency ranges. The parasitic capacitance does not exist in this block as its input terminals are internally grounded [16]. CDBA also offers a low impedance voltage-mode output, which is necessary for cascading.

The inverse filter configuration reported in [16][17][18][19] use two CDBAs. Herencsar et al. [8] cannot realize the inverse band reject (IBR) filter. Pandey et al. [18] introduced a topology that can realize all the five inverse filter functions, Bhagat et al. [19] realize IBR and IAP filters only. Bhagat et al. [20] realize only ILP, IHP, and IBP filters.

Paul et al. [21] proposed a single CDBA based inverse filter configuration. They could not realize an inverse all all-pass (IAP) filter.

We propose a single CDBA configuration that can realize all the five generic filters. The capacitors are either physically or virtually grounded.

II. THE PROPOSED FILTER CONFIGURATION

The proposed filter configuration is shown in Fig. 1, where the symbol of CDBA, equivalent circuit, and realization using AD844 are shown in Fig. 2. Terminal characteristics of CDBA are given by

$$V_p = V_n = 0, V_w = V_z, I_z = I_p - I_n \quad (1)$$

Routine analysis of the circuit gives

$$\frac{V_o}{V_i} = \frac{Y_1}{Y_3 - Y_2} \quad (2)$$

Note that interchanging Y_2 and Y_3, the transfer function becomes negative.

Let

$$Y_1 = sC_1 + \frac{1}{R_1}, \qquad Y_2 = \frac{sC_2}{1 + sC_2R_2} \quad (3)$$

Then (2) gives

$$\frac{V_o}{V_i} = \frac{1}{R_1}\left[\frac{N(s)}{Y_3(1 + sC_2R_2) - sC_2}\right] \quad (4)$$

where

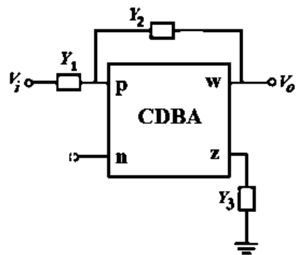
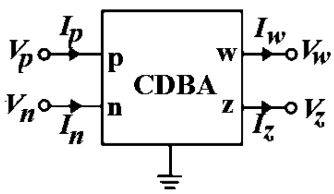
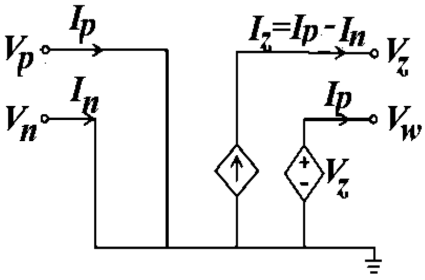


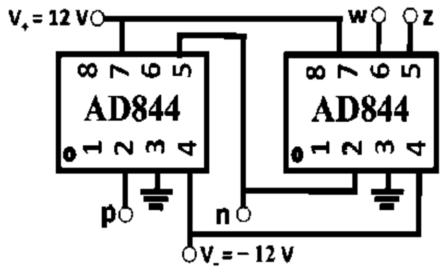
Fig. 1. Proposed inverse filter realization



(a)



(b)



(c)

Figure 1. (a) Symbol of CDBA, (b) Equivalent circuit, (c) Realization for CDBA using AD844

$N(s) = s^2C_1R_1C_2R_2 + s(C_1R_1 + C_2R_2) + 1$ (5)

A negative term in the denominator of (4) gives the facility to adjust the coefficients of various terms to yield different types of filters. The choice of Y_3 and the conditions for various filters are summarized in Table 1. Various filter circuits are shown in Fig. 3, and the corresponding transfer functions are given in Table 2. To conserve space, we will demonstrate the design of the inverse all-pass (IAP) filter.

From (4), when

$$Y_3 = \frac{1 + sC_3R_3}{R_3} \quad (6)$$

$$\frac{V_o}{V_i} = \frac{R_3}{R_1}\left[\frac{s^2C_1R_1C_2R_2 + s(C_1R_1 + C_2R_2) + 1}{s^2C_3R_3C_2R_2 + s(C_3R_3 + C_2R_2 - C_2R_3) + 1}\right] \quad (7)$$

For IAP, the conditions are

$$C_1R_1C_2R_2 = C_3R_3C_2R_2 \rightarrow C_1R_1 = C_3R_3 \quad (8)$$

and

$$C_3R_3 + C_2R_2 - C_2R_3 = -C_1R_1 - C_2R_2 \quad (9)$$

$$\rightarrow R_3 = \left(2R_2 + \frac{C_1R_1}{C_2}\right)\left(\frac{C_2}{C_2 - C_3}\right) \quad (10)$$

Let

$$C_3 = aC_2,\ \ C_1 = bC_2 \quad (11)$$

The (10) reduces to

$$R_3 = \frac{2R_2 + bR_1}{(1 - a)} \quad (12)$$

From (8) and (11)

$$\rightarrow R_3 = \frac{bR_1}{a}. \quad (13)$$

From (12) and (13)

$$\frac{bR_1}{a} = \frac{2R_2 + bR_1}{(1 - a)}. \quad (14)$$

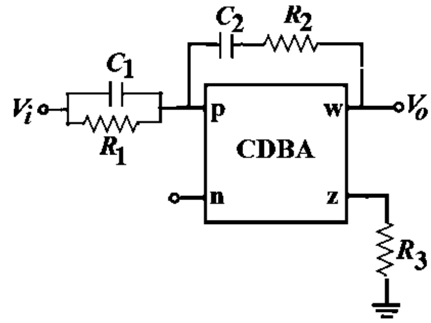
Obviously, $a < 1$. Let

$$a = \frac{1}{3} \quad (15)$$

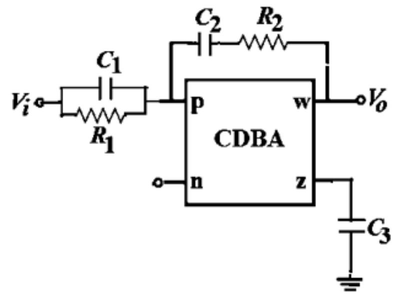
Then (14) gives

Table 1: Filter conditions

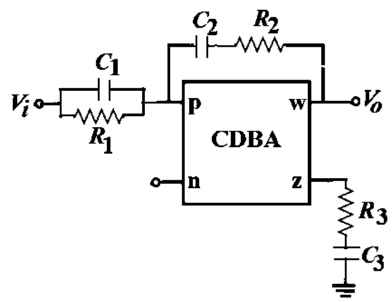
Filter	Y_3	Conditions
ILP	$1/R_3$	$C_1=C_2=C_3=C$, $R_1=R_2=R_3=R$,
IHP	sC_3	
IBP	$sC_3/(1+ sC_3R_3)$	$C_1=(1/2)C, C_2=C, C_3=2C$, $R_1=2R$, $R_2=R$, $R_3=(1/2)R$
IBR	$(1/R_3)+sC_3$	$C_1=C_3=C/2$, $C_2=C$ $R_1=R_3=2R$, $R_2=R$
IAP	$(1/R_3)+sC_3$	$C_1=C_2=C$, $C_3=(1/3)C$, $R_1=2R$, $R_2=R$, $R_3=6R$



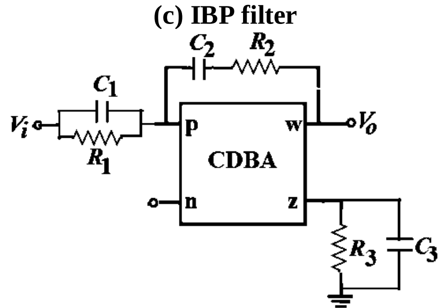
(a) ILP filter



(b) IHP filter



(c) IBP filter



(d) IBR filter and (e) IAP filter

Figure. 2. Realization of various inverse filters

Table 2: Filter transfer functions

Filter	Transfer function $\frac{V_o}{V_i}$
ILP	$\left[\frac{s^2C^2R^2+2sCR+1}{1}\right]$
IHP	$\left[\frac{s^2C^2R^2+2sCR+1}{s^2C^2R^2}\right]$
IBP	$\left[\frac{s^2C^2R^2+2sCR+1}{sCR}\right]$
IBR	$\left[\frac{s^2C^2R^2+2sCR+1)}{s^2C^2R^2+1}\right]$
IAP	$3\left[\frac{s^2C^2R^2+2sCR+1}{s^2C^2R^2-2sCR+1}\right]$

$$b = \frac{2R_2}{R_1}. \quad (16)$$

Let us choose $b = 1$, then

$$R_1 = 2R_2 \quad (17)$$

Then from (13),

$$R_3 = 3R_1 \quad (18)$$

and from (11)

$$C_3 = \frac{1}{3}C_2, \qquad C_1 = C_2 \quad (19)$$

Equations (17)-(18) are the design relations for the IAP filter. For this filter the gain constant = $R_3/R_1 = 3$. Note that there are many choices for a and b and, therefore, many possible circuits.

The central frequency w_o and the quality factor Q for all the filters are

$$\omega_o = \frac{1}{\sqrt{C_1C_2R_1R_2}}, \quad Q = \frac{\sqrt{C_1C_2R_1R_2}}{C_1R_1 + C_2R_2} \quad (20)$$

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