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Realizations of Conventional and Inverse Voltage Transfer Functions

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Abstract - *A voltage-mode (VM) multifunction configuration for the realization of conventional and inverse active filters (IAF) using two current differencing buffered amplifiers and six passive elements is presented. The proposed structure can realize all the basic filters from the same circuit topology by appropriate choice of the branch impedances.*

Keywords - *Analog Filters, Inverse Filters, Analog Signal Processing, Current Differencing Buffered Amplifier*

I. INTRODUCTION

There are several conventional and inverse voltage transfer function realizations available in the literature [1]-[35] using various electron devices, such as CDBA (Current differencing buffered amplifier), OA (operational amplifier), CFOA (Current feedback operational amplifier), CCII (current conveyor II), FTFN (Four terminal floating nullor), OTRA (Operational trans-resistance amplifier), CDTA (current difference trans amplifier), OTA (Operational trans-conductance amplifier, DDCC (differential difference current conveyors, VDTA (voltage differencing transconductance amplifier).

Inverse analog active filters are an important class of analog signal processing circuits from the view point of some applications in the areas where the distortion introduced in the signal transmission path may be corrected by making the signal pass through an inverse filter whose characteristics are the reciprocal of the original system which has introduced the distortion. Over the years, several active inverse analog filter designs employing different active building blocks [11]–[34] have been reported. Bhagat *et al* [34] gives a CDBA configuration which can realize both conventional and inverse filters. In this paper, we present some more configurations using OA, CCII, CFA and FTFN that can realize both conventional and inverse filters.

II. PROPOSED FILTER REALIZATIONS

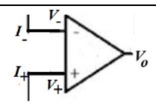
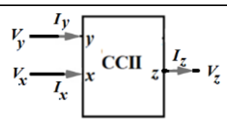
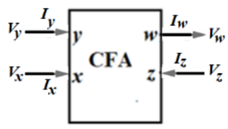
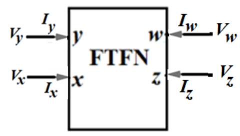
The symbol and terminal characteristics for OA, CCII, CFA and FTFN are shown in Table 1. All the configurations shown in Fig. 1 has a voltage transfer function

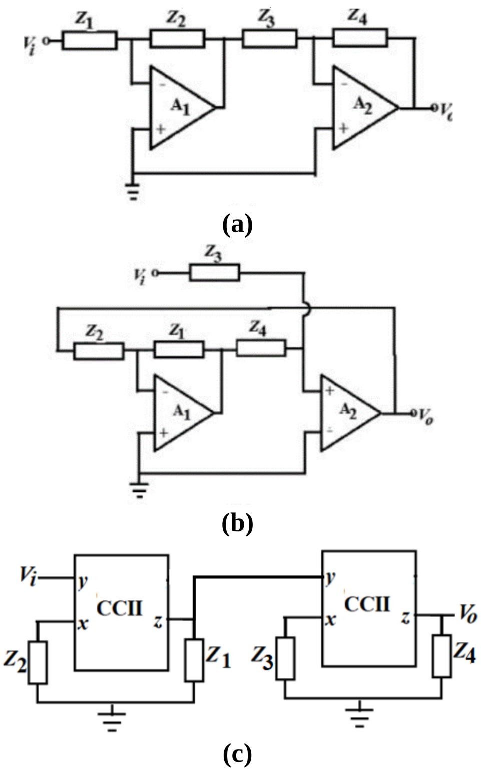
$$\frac{V_o}{V_i} = \frac{Z_2 Z_4}{Z_1 Z_3}.$$

The transfer function does not change if Z_2 and Z_4 and/or Z_1 and Z_3 are interchanged. However, if Z_2 is interchanged with Z_1 or Z_3 and Z_4 is interchanged with Z_1 or Z_3, the transfer functions become inverse function.

Tables 2 and 3 give the choices of the components and corresponding filter functions for various conventional and inverse filters, respectively. There is one low pass and one high pass and 4 cases under both CBP and IBP categories.

Table 1: Symbols and terminal characteristics of the devices

Device	Symbol	Terminal character-istics
OA		$I_-=I_+=0$, $V_- = V_+$
CCII		$I_y= 0$, $I_x=I_z$ $V_x = V_y$
CFA		$I_y= 0$, $I_x=I_z$ $V_x = V_y$ $V_w = V_z$
FTFN		$I_x=I_y=0$, $I_z=I_w$ $V_x = V_y$ $V_w = V_z$



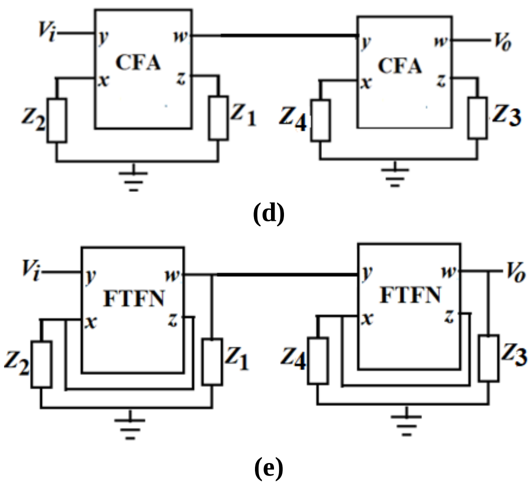


Figure 1: Various configurations (a) OA, (b) OA (c) CCII (d) CFA (e) FTFN

If we choose all the resistors of value R and all capacitors of value C, the transfer functions reduce as shown in Table 3.

Table 2: Conventional filters

Filter type	Z_1	Z_2	Z_3	Z_4	Conventional Filter function
CLP	R_1	$\frac{R_2}{1+sC_2R_2}$	R_3	$\frac{R_4}{1+sC_4R_4}$	$\frac{\left(\frac{1}{R_1R_3C_2C_4}\right)}{s^2+\left(\frac{1}{R_2C_2}+\frac{1}{R_4C_4}\right)s+\frac{1}{R_2R_4C_2C_4}}$
CHP	$\frac{1+sC_1R_1}{sC_1}$	R_2	$\frac{1+sC_3R_3}{sC_3}$	R_4	$\frac{\left(\frac{R_2R_4}{R_1R_3}\right)s^2}{s^2+\left(\frac{1}{R_1C_1}+\frac{1}{R_3C_3}\right)s+\frac{1}{R_1R_3C_1C_3}}$
CBP1	$\frac{1+sC_1R_1}{sC_1}$	R_2	R_3	$\frac{R_4}{1+sC_4R_4}$	$\frac{\left(\frac{R_2}{R_1R_3C_4}\right)s}{s^2+\left(\frac{1}{R_1C_1}+\frac{1}{R_4C_4}\right)s+\frac{1}{R_1R_4C_1C_4}}$
CBP2	R_1	R_2	$\frac{1+sC_3R_3}{sC_3}$	$\frac{R_4}{1+sC_4R_4}$	$\frac{\frac{R_2}{R_1R_3C_4}s}{s^2+\left(\frac{1}{R_3C_3}+\frac{1}{R_4C_4}\right)s+\frac{1}{R_3R_4C_3C_4}}$
CBP3	$\frac{1+sC_1R_1}{sC_1}$	$\frac{R_2}{1+sC_2R_2}$	R_3	R_4	$\frac{\frac{R_4}{R_1R_3C_2}s}{s^2+\left(\frac{1}{R_1C_1}+\frac{1}{R_2C_2}\right)s+\frac{1}{R_1R_2C_1C_2}}$
CBP4	R_1	$\frac{R_2}{1+sC_2R_2}$	$\frac{1+sC_3R_3}{sC_3}$	R_4	$\frac{\left(\frac{R_4}{R_1R_3C_2}\right)s}{s^2+\left(\frac{1}{R_2C_2}+\frac{1}{R_3C_3}\right)s+\frac{1}{R_2R_3C_2C_3}}$

Table 3: Inverse filters

Filter type	Z1	Z2	Z3	Z4	Inverse filter function,
ILP	$\frac{R_1}{1+sC_1R_1}$	R_2	$\frac{R_3}{1+sC_3R_3}$	R_4	$\frac{1}{\frac{\left(\frac{1}{R_2R_4C_1C_3}\right)}{s^2+\left(\frac{1}{R_1C_1}+\frac{1}{R_3C_3}\right)s+\frac{1}{R_1R_3C_1C_3}}}$
IHP	R_1	$\frac{1+sC_2R_2}{sC_2}$	R_3	$\frac{1+sC_4R_4}{sC_4}$	$\frac{1}{\frac{\left(\frac{R_1R_3}{R_2R_4}\right)s^2}{s^2+\left(\frac{1}{R_2C_2}+\frac{1}{R_4C_4}\right)s+\frac{1}{R_2R_4C_2C_4}}}$
IBP1	R_1	$\frac{R_2}{1+sC_2R_2}$	$\frac{1+sC_3R_3}{sC_3}$	R_4	$\frac{1}{\frac{\left(\frac{R_4}{R_1R_3C_2}\right)s}{s^2+\left(\frac{1}{R_2C_2}+\frac{1}{R_3C_3}\right)s+\frac{1}{R_2R_3C_2C_3}}}$
IBP2	$\frac{1+sC_1R_1}{sC_1}$	$\frac{R_2}{1+sC_2R_2}$	R_3	R_4	$\frac{1}{\frac{\frac{R_4}{R_1R_3C_2}s}{s^2+\left(\frac{1}{R_1C_1}+\frac{1}{R_2C_2}\right)s+\frac{1}{R_1R_2C_1C_2}}}$
IBP3	R_1	R_2	$\frac{1+sC_3R_3}{sC_3}$	$\frac{R_4}{1+sC_4R_4}$	$\frac{1}{\frac{\frac{R_2}{R_1R_3C_4}s}{s^2+\left(\frac{1}{R_3C_3}+\frac{1}{R_4C_4}\right)s+\frac{1}{R_3R_4C_3C_4}}}$
IBP4	$\frac{1+sC_1R_1}{sC_1}$	R_2	R_3	$\frac{R_4}{1+sC_4R_4}$	$\frac{1}{\frac{\left(\frac{R_2}{R_1R_3C_4}\right)s}{s^2+\left(\frac{1}{R_1C_1}+\frac{1}{R_4C_4}\right)s+\frac{1}{R_1R_4C_1C_4}}}$

Table 3. Functions when all *R*s are equal to *R* and all *C*s are equal to *C*

Filter type	Conventional filter function	Inverse filter function
CLP	$\frac{\left(\frac{1}{R^2C^2}\right)}{D(s)}$	$\frac{1}{\left\{\frac{\left(\frac{1}{R^2C^2}\right)}{D(s)}\right\}}$
CHP	$\frac{s^2}{D(s)}$	$\frac{1}{\left\{\frac{s^2}{D(s)}\right\}}$
CBP1 CBP2 CBP3 CBP4	$\frac{\left(\frac{1}{RC}\right)s}{D(s)}$	$\frac{1}{\left\{\frac{\left(\frac{1}{RC}\right)s}{D(s)}\right\}}$

where

$$D(s) = s^2 + \left(\frac{2}{RC}\right)s + \frac{1}{R^2C^2}$$

Now

$$\omega_o = \frac{1}{RC}, \quad Q = \frac{1}{2}.$$

Tuning of ω_o and Q is easier, if the values or R and C are not taken equal.

III. CONCLUSION

A VM multifunction configuration for the realization of conventional and IAF using two current differencing buffered amplifiers and six passive elements has been presented. The proposed structure can realize all the basic filters from the same circuit topology by appropriate choice of the branch impedances.

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