A STUDY ON BAND-REJECT FILTER DESIGN USING THIRD GENERATION CURRENT CONVEYORS (CCIII)

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ABSTRACT

In this paper, new designs of band-reject (BR) filters using CCIII's, are proposed. First, a circuit, which has low-pass (LP) and high-pass (HP) characteristics on different branches is designed using one CCIII+, two resistors, and two capacitors. Then, a CCIII- is added to the circuit in order to combine HP and LP characteristics to obtain a band-reject characteristic. Finally, another CCIII- is used to obtain high output impedance of the BR characteristic. Two designs, with BR characteristics are proposed and investigated in this paper. To confirm the theoretical analysis, all circuits are simulated, comparative with the ideal response, using PSPICE.

I.INTRODUCTION

Current conveyors and unity-gain amplifiers are widely used by analog designers especially in applications of signal processing and active network synthesis [1-2]. Recently third generation of this block has also been proposed by Fabre et al [3]. The third generation current conveyors (CCIIIs) can be considered as a current controlled current source with a unity gain. This type of the current conveyor is useful to take out the current flowing through a floating branch of a circuit and can be utilized in realization of various multifunction filters, inductance simulation and all pass sections [4-9]. However, none of the proposed circuits in the literature realizes BR filter characteristics. In this paper we proposed a new configuration, which realizes BR filter characteristics.

II.THE THIRD GENERATION CURRENT CONVEYOR (CCIII)

The electrical symbol of the CCIII± is shown in Figure 1. Mathematical representation of the CCIII± is given by,

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \tag{1}$$

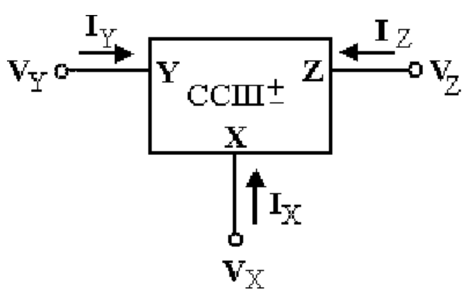

Figure 1. Electrical symbol of the CCIII±

III. CIRCUITS WITH HP AND LP CHARACTERISTICS

The general circuit suitable for realizing HP and LP filter characteristics is shown in Figure 2.

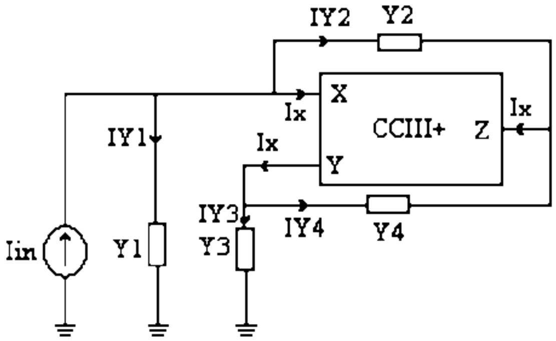

Figure 2. The general circuit

Routine analysis of the circuit gives the following transfer functions,

$$TF_1 = \frac{I_{Y1}}{I_{in}} = \frac{Y_1 Y_2}{Y_1 Y_2 + 2Y_2 Y_3 + Y_3 Y_4} \tag{2}$$

$$TF_2 = \frac{I_{Y4}}{I_{in}} = \frac{Y_3 Y_4}{Y_1 Y_2 + 2Y_2 Y_3 + Y_3 Y_4} \tag{3}$$

Selecting Y_1=sC_1, Y_2=sC_2, Y_3=R_3, and Y_4=R_4, TF_1 and TF_2 becomes;

$$TF_1 = \frac{s^2 C_1 C_2}{s^2 C_1 C_2 + 2sC_2 G_3 + G_3 G_4} \tag{4}$$

$$TF_2 = \frac{G_3 G_4}{s^2 C_1 C_2 + 2sC_2 G_3 + G_3 G_4} \tag{5}$$

where $G = R^{-1}$.

The circuits are simulated in PSPICE program using MIETEC 1.2µ CMOS process model. The CCIII implementation is shown in Figure 3. From the simulations of TF_1 and TF_2 which are shown in Figures 4 and 5, respectively. It can be seen that TF_1 has HP and TF_2 has LP filter characteristics. In the simulations the component values were chosen as C_1=C_2=40pF, R_3=10KΩ and R_4=1KΩ. The natural pole frequency and quality factor of the filters are calculated as f_o=1.25MHz and Q=1.58, respectively. All the circuit models, and Pspice codes for the simulations can be found in [10].

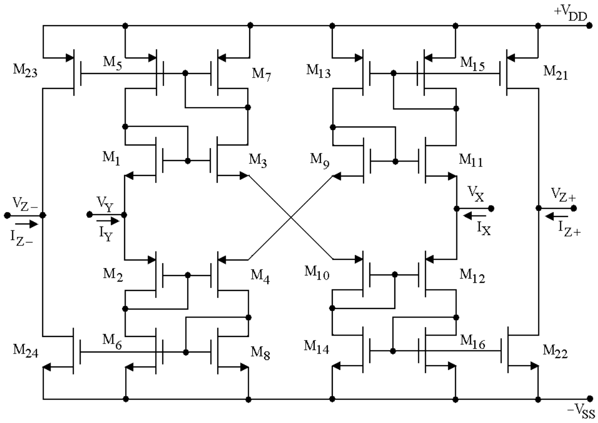

Figure 3. The CCIII± implementation for the simulations

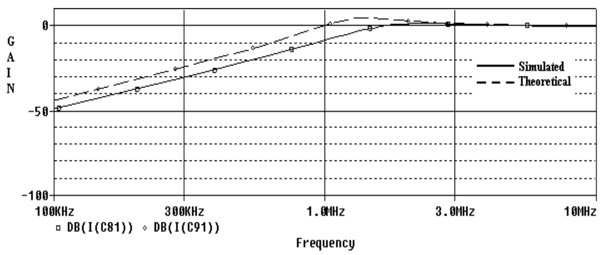

Figure 4. TF_1 simulation

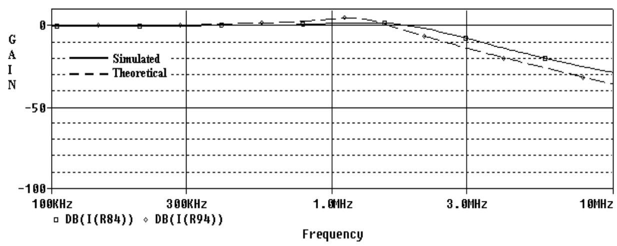

Figure 5. TF_2 simulation

Selecting Y_1=R_1, Y_2=R_2, Y_3=sC_3, Y_4=sC_4, TF_1 and TF_2 becomes;

$$TF_1 = \frac{G_1 G_2}{s^2 C_3 C_4 + 2sG_2 C_3 + G_1 G_2} \tag{6}$$

$$TF_2 = \frac{s^2 C_3 C_4}{s^2 C_3 C_4 + 2sG_2 C_3 + G_1 G_2} \tag{7}$$

In this case, it can be seen that TF_1 has LP and TF_2 has HP filter characteristics, which are simulated in Figures 6 and 7. The components are chosen as R_1=1kΩ, R_2=100kΩ, C_3=C_4=40pF. The natural pole frequency and quality factor of the filters are calculated as f_o=397kHz and Q=5, respectively.

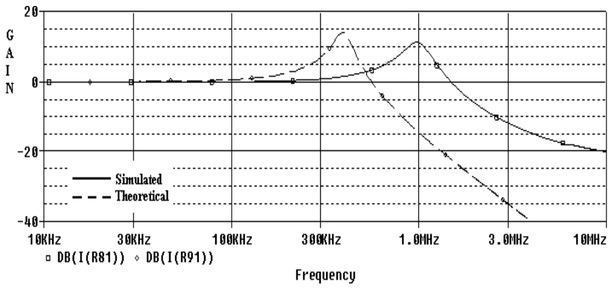

Figure 6. TF_1 simulation

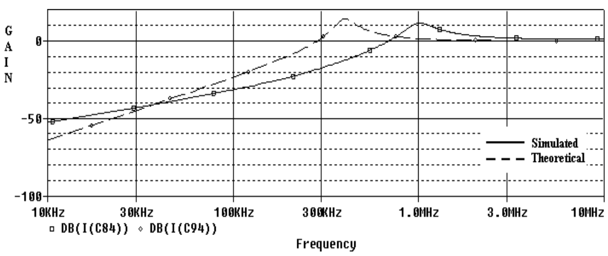

Figure 7. TF_2 simulation

IV. OBTAINING THE BR CHARACTERISTICS

The BR characteristic is obtained with a summation of LP and HP characteristics by adding a CCIII- to the general circuit. The resulting circuit is shown in Figure 8.

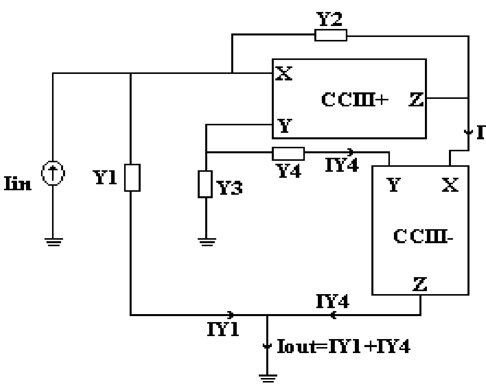

Figure 8. Circuit for obtaining BR characteristic

The transfer function $TF=TF_1+TF_2$ is given by

$$TF = \frac{I_{out}}{I_{in}} = \frac{Y_1Y_2 + Y_3Y_4}{Y_1Y_2 + 2Y_2Y_3 + Y_3Y_4} \tag{8}$$

Selecting $Y_1=sC_1$, $Y_2=sC_2$, $Y_3=R_3$, and $Y_4=R_4$, TF becomes

$$TF = \frac{s^2C_1C_2 + G_3G_4}{s^2C_1C_2 + 2sC_2G_3 + G_3G_4} \tag{9}$$

It can be seen that TF has BR filter characteristics, which is simulated in Figure 9. The components were chosen as C_1=C_2=40pF, R_3=10kΩ and R_4=1kΩ in the simulation. The natural pole frequency and quality factor of the filter is calculated as f_o=1.25MHz and Q=1.58, respectively.

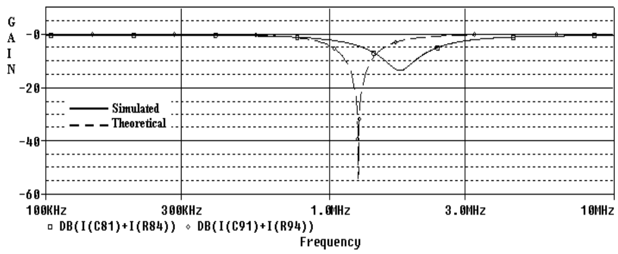

Figure 9. TF simulation for equation 9

Selecting $Y_1=R_1$, $Y_2=R_2$, $Y_3=sC_3$, and $Y_4=sC_4$, TF becomes as described in equation 10.

$$TF = \frac{s^2C_3C_4 + G_1G_2}{s^2C_3C_4 + 2sC_3G_2 + G_1G_2} \tag{10}$$

It can be seen that TF_{Iout} has BR filter characteristics which is simulated in Figure 10 with components chosen as C_3=C_4=40pF and R_1=1KΩ, R_2=100KΩ in the simulation. The natural pole frequency and quality factor of the filter is calculated as f_o=397kHz and Q=5, respectively.

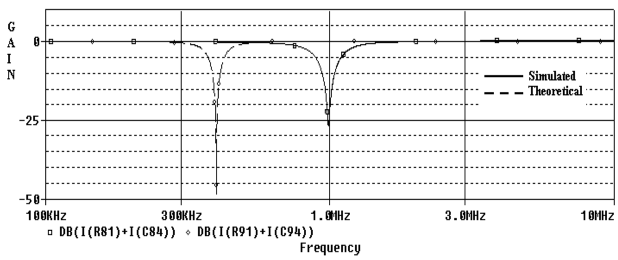

Figure 10. TF simulation for equation 10

V. OBTAINING THE HIGH OUTPUT IMPEDANCE

The current I_{out}, flowing through the ground, can be obtained as high impedance output by adding an additional CCIII- to the circuit in Figure 8. The resulting circuit is shown in Figure 11.

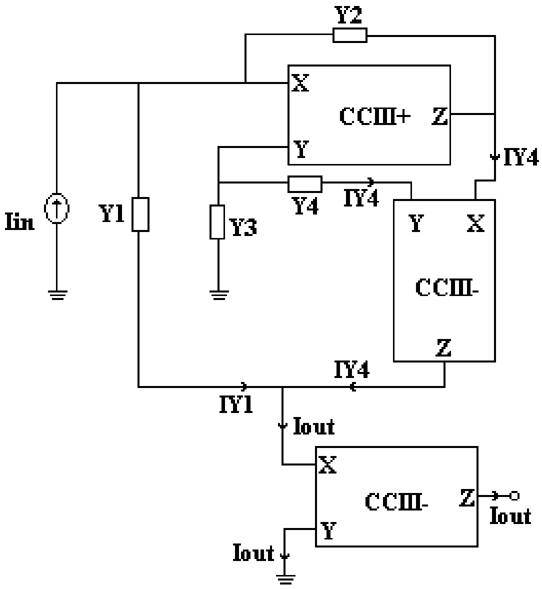

Figure 11. Obtaining high impedance output current

VI. CONCLUSION

In this paper, band-reject or notch filters are designed with the third generation current conveyors and two example circuits are investigated. Two resistors, two capacitors, one CCIII+, and two CCIII-s were used in the applications. One of the CCIII- was used to obtain high output impedance. BR filter characteristics are obtained where the circuit characteristics and frequency rejected vary due to the values of the passive components in the circuit.

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