CCCDBA Based Implementation of Voltage Mode Third Order Filters

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Abstract. In the present paper implementation of third order low pass, high pass filters have been proposed by using current-controlled current differencing buffered amplifier (CCCDBA). In the present work, an effort has been made to simulate the third order doubly-terminated LC ladder low pass filter, third order doubly-terminated LC ladder high pass filters using CCCDBA. Here, in each circuit more than one CCCDBA and few grounded capacitor without have been utilized. The designed circuits are very suitable for integrated circuit and very easy in implementation. The circuits' performance is simulated through PSPICE and its simulated results obtained so is comparable to the theoretical one.

Keywords: Current-controlled current differencing buffered amplifier (CCCDBA), Doubly Terminated LC Ladder, Voltage mode differentiator, Third order high pass filter, voltage mode integrator, Third order low pass filter, Third Order Leapfrog Filter.

1 Introduction

Filters have found wide applications in the field of instrumentation, automatic control, and communication. A basic approach for building higher-order filters is to emulate a passive LC ladder filter which possesses low sensitivities in the pass band. Electronically tunable current mode ladder filters using current controlled CDBA has been presented in this paper. In this paper we have presented the design and simulation of third order doubly-terminated LC ladder low pass filter, third order doubly-terminated LC ladder high pass filter.

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2 Operation

A current differencing buffered amplifier (CDBA), which is a new active circuit building block especially suitable for the realization of a class of continuous-time filters, has been introduced, whose bipolar-based realization is introduced and used for the realization of active and passive filters. It offers several advantageous features such as:-

a) high-slew rate,
b) freedom from parasitic capacitances,
c) wide bandwidth and,
d) Simple implementation.

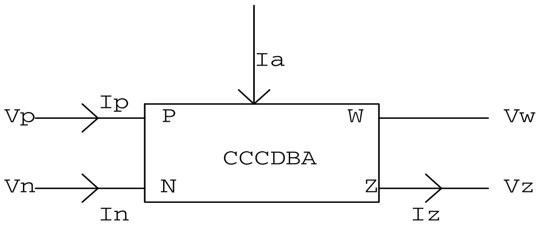

Fig. 1. Symbolic representation of current-controlled CDBA [7],[8]

Since the proposed circuits are based on CCCDBAs, a brief review of CCCDBA is given here. CCCDBA is a translinear based current-controlled current differencing buffered amplifier (CC-CDBA's) whose parasitic input resistances can be varied electronically. Basically, the CCDBA is a four-terminal active element. For ideal operation, it's current and voltage relations described by the equation-1. [11],[12],[13].

From the circuit operation, the current-voltage characteristics of CC-CDBA can be expressed by the following matrix.

$$\begin{bmatrix} v_p \\ v_n \\ i_z \\ v_w \end{bmatrix} = \begin{bmatrix} 0 & 0 & R_X & 0 \\ 0 & 0 & 0 & R_X \\ 0 & 0 & 1 & -1 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} v_z \\ i_z \\ i_p \\ i_n \end{bmatrix} \tag{1}$$

2.1 Third Order Doubly-Terminated Lc Ladder Low Pass Filters

In this section, voltage-mode leapfrog filter realization is shown for a third-order low pass filter[8],. Figure-1 shows a third-order doubly terminated LC filter.

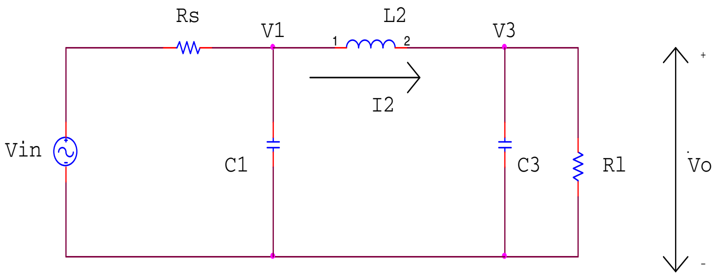

Fig. 2. Doubly Terminated LC Ladder Filter (Low pass Section)

Figure-2 shows the block diagram of the leapfrog representation of the LC filters[1], [8]. From Figure-2 it is obvious that the low pass filter can be constructed with two lossy integrators and a lossless integrator. The CCCDBA implementation of low pass filter is shown in Figure-3. Where

$$V_1 = \frac{\left(V_{in} - \hat{V}_2\right)}{1 + sC_1 R} \tag{2}$$

$$\hat{V}_2 = \frac{R}{sL_2}\left(V_1 - V_2\right) \tag{3}$$

$$V_O = V_3 \tag{4}$$

$$V_3 = \frac{\hat{V}_2}{1 + sC_2 R} \tag{5}$$

The transfer function of the low pass filter is determined to be as given by the equation-6.

$$\frac{V_o(s)}{V_i(s)} = \frac{\left(\frac{R}{R_1}\right)\left(\frac{1}{C^3 R^2 R_1}\right)}{s^3 + 2s^2\left(\frac{1}{CR}\right) + 2s\left[\frac{(2R + R_1)}{C^2 R^2 R_1}\right] + \frac{2}{C^3 R^2 R_1}} \tag{6}$$

In the above equation we have assumed that:

$R_{x1} = R_{x2} = R_{x3} = R_{x4} = R_{x5} = R_{x7} = R_{x8} = R_{x9} = R_{x11} = R_{x12} = R_{x13} = R_1$ and $R_{x6} = R_{x10} = R_{x14} = R$. Also, $C_1 = C_2 = C_3 = C$.

From the above transfer function of equation-6 we obtain the expression for cut-off frequency as: -

$$\omega_o = \sqrt[3]{\frac{2}{C^3 R^2 R_1}} \tag{7}$$

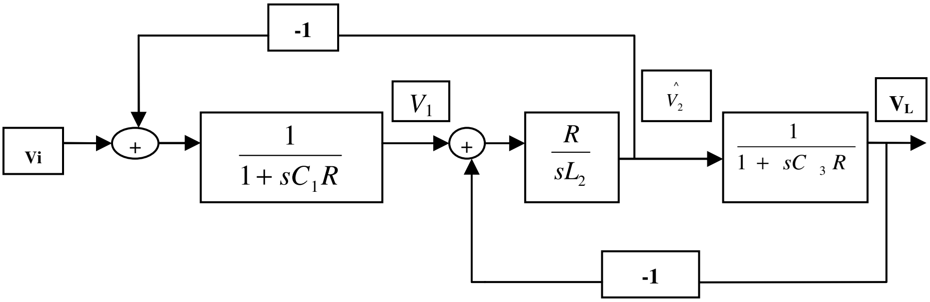

Fig. 3. Block Diagram of Third Order Leapfrog Filter (Low pass Section)

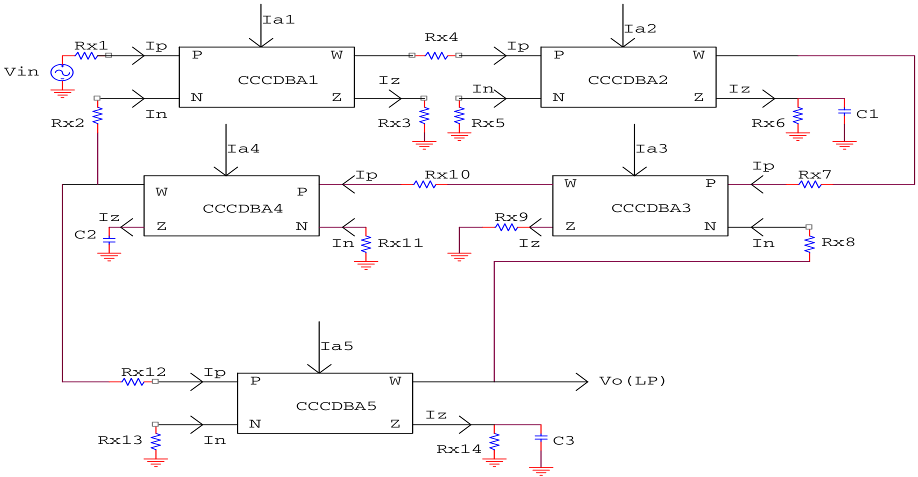

Fig. 4. Circuit Diagram of Third Order Doubly Terminated LC Ladder Leapfrog Low pass Filter Using CCCDBA

2.2 Third Order Doubly-Terminated Lc Ladder High Pass Filter

Figure-5 represents the circuit of a doubly-terminated LC ladder high pass filter, which is obtained by interchanging the position of L and C in the circuit of low pass section [2], [3] as shown in Figure-2. To obtain the circuit realization of the filter in the form of adders, sub tractors and integrators mathematical calculations are carried out and we arrive at the following results:

$$\hat{V}_2 = V_{in} - V_1 - \frac{R}{sL_1} V_1 \tag{8}$$

$$V_3 = V_1 - \frac{\hat{V}_2}{sC_2 R} \quad (9)$$

$$V_1 = V_3 + \frac{\hat{V}_2}{sC_2 R} \quad (10)$$

$$\hat{V}_2 = V_3 + \frac{R}{sL_3} V_3 \quad (11)$$

$$V_O = V_3 \quad (12)$$

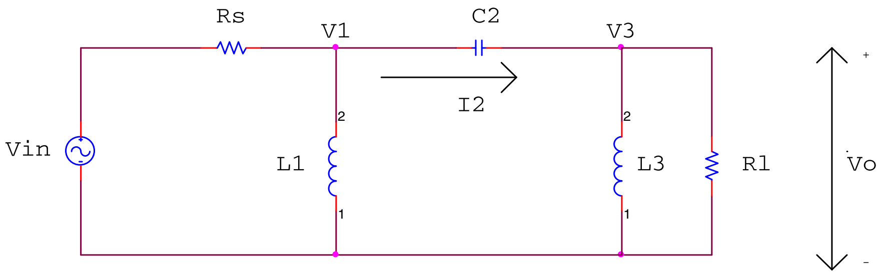

Fig. 5. Doubly Terminated LC Ladder High Pass Filter

With the help of the above four equations we can obtain the block-diagram of Figure-5 which is depicted in Figure-6 shown below.

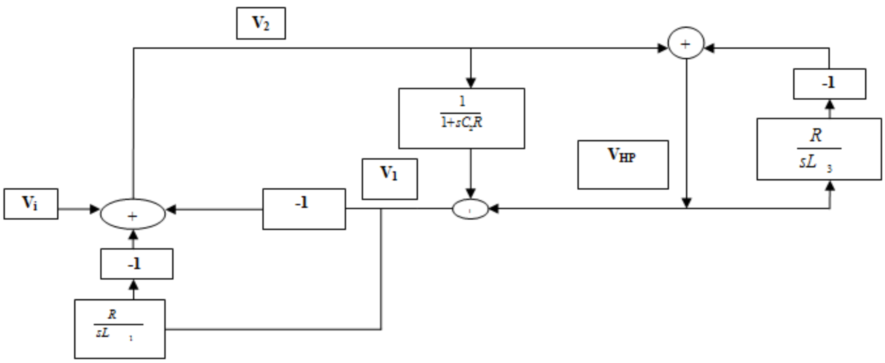

Fig. 6. Block Diagram of Third Order Leapfrog Filter (High pass Section)

The CCCDBA implementation of high pass filter [6] is shown in Figure-7. The transfer function of the circuit of Figure-6 is determined and it is given by equation-12.

$$\frac{V_o(s)}{V_i(s)} = \frac{s^3\left(\frac{R}{R_1}\right)\left(\frac{1}{C^3R^2R_1}\right)}{s^3 + 2s^2\left(\frac{1}{CR}\right) + 2s\left[\frac{(2R+R_1)}{C^2R^2R_1}\right] + \frac{2}{C^3R^2R_1}} \tag{13}$$

In the above equation we have assumed that:

$R_{x8} = R_1 = R_{x16} = R_{x10} = R$ and also, $C_1 = C_2 = C_3 = C$.

From the above transfer function of equation-13 we obtain the expression for cut-off frequency as: -

$$\omega_o = \sqrt[3]{\frac{2}{C^3R^2R_1}} \tag{14}$$

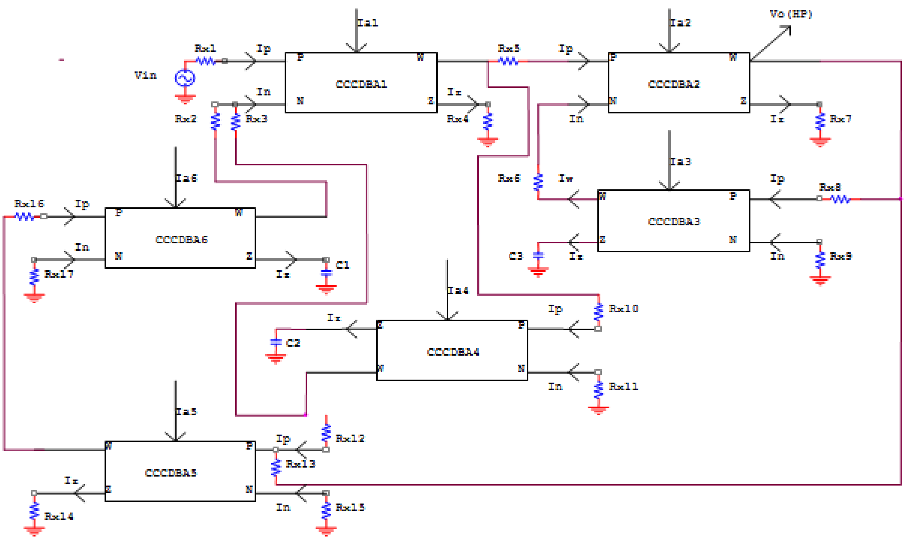

Fig. 7. Circuit Diagram of Third Order Doubly Terminated LC Ladder Leapfrog High pass Filter Using CCCDBA

3 Simulation Results

Figure-8 depicts the SPICE simulation results of the proposed third order LC ladder low pass filter circuit which gives the value of cut-off frequency to be 239.883 KHz. Figure-9 depicts the SPICE simulation results of the proposed third order LC ladder high pass filter circuit which gives the value of cut-off frequency to be 164.059 KHz .

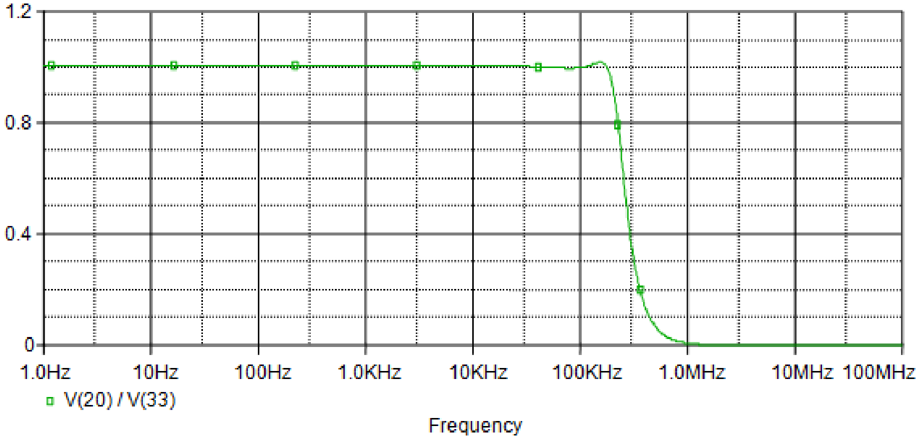

Fig. 8. Response of Third Order LC Ladder Low pass Filter

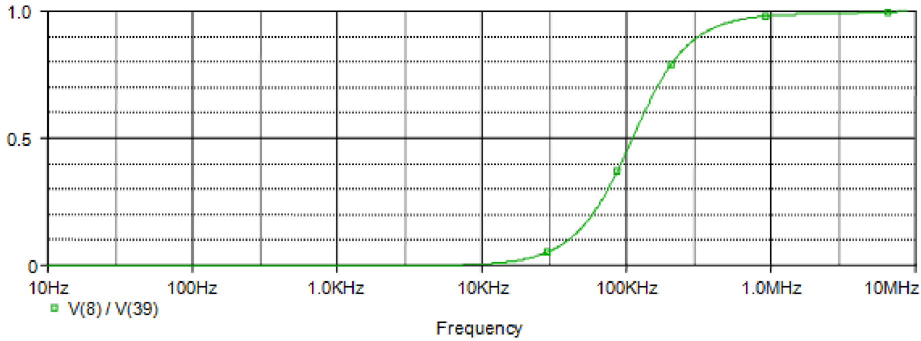

Fig. 9. Response of Third Order LC Ladder High Pass Filter

4 Conclusions

We observe that the realized filter works in accordance with the theoretical values for Butterworth response with R = 975Ω and R_1 = 130Ω, and the capacitors to be equal C = 1nF, which gives cutoff frequency to be approximately equal to 402.574 KHz. we observe that the realized filter works in accordance with the theoretical values for Butterworth response with R = 780Ω and the capacitors to be equal C = 1nF, which gives cutoff frequency to be approximately equal to 119.326 KHz. In this chapter we have realized higher order current-mode continuous-time filters using current-controlled CCCDBA. We have focused our attention on the implementation and design of doubly terminated LC ladder leapfrog filters. As an example we have realized a third order low pass, third order high pass filter.

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