Design of CCCDBA Based Voltage Mode Differentiator and Integrator

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Abstract **- In this paper a voltage mode differentiator (First order high pass filter) and voltage mode integrator (First order low pass filter) have been proposed by using current-controlled current differencing buffered amplifier (CCCDBA). In the present work, an effort has been made to control the first order filters parameters electronically, adjusting bias current of CCCDBA. The designed circuits are very suitable for integrated circuit and very easy in implementation. The circuit performance is simulated through PSPICE and its simulated results obtained so is comparable to the theoretical one.**

Key Words **- Voltage mode differentiator, First order high pass filter, voltage mode integrator, First order low pass filter, current-controlled current differencing buffered amplifier (CCCDBA), integrated circuit.**

I. Introduction

Integrator and differentiator are important building block, which are suitable for active filter design in integrated circuits. Very few approaches of designing voltage mode integrator and differentiator are widely discussed earlier in literature, some of these are based on: op-amp,switched-capacitor, operational transconductance amplifier (OTA)-C, current-mode building blocks for example current conveyor of different generations.

In this article we present voltage mode integrator and differentiator using CCCDBA [1],[3],[4],[5],[6], which are very useful in signal processing circuits. Here, no external resistors are employed, which leads to small size of monolithic chip, electronic tunability, low power consumption and less complex design? The features of proposed circuits are: the proposed circuit employ only one CCCDBA, only single grounded capacitor, which is convenient to realize in an IC, and it's time constant can be controlled via input bias current.

II. Operation

A. Current-Controlled Current Differencing Buffered Amplifier (CCCDBA)

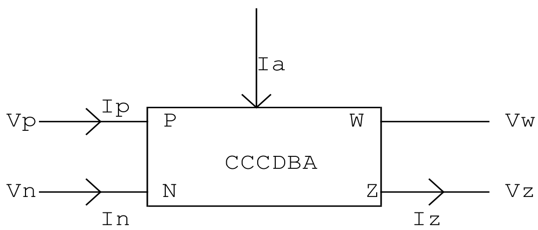

Fig. 1: Symbolic representation of current-controlled CDBA [7],[8]

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.

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

B. Voltage-Mode Active Functional Building Blocks Used In Filter Synthesis

The basic building blocks which are required for the implementation of voltage-mode active filters are:

1) Differentiators and
2) Integrators (Lossy and Lossless)

These basic building blocks required for the realization of active filters are being implemented with the help of Current-controlled Current Differenced Buffered Amplifier (CC-CDBA) and they are discussed in subsequent section.

B.1. ***Voltage-Mode Differentiator***

Such circuits present an output voltage that is proportional to the differential of the input voltage. An ideal differentiator also behaves as a first-order high pass filter which can be verified by the simulation results obtained so. The circuit implementation using CCCDBA [7],[8],[9],[10] is shown in the Fig.-1 along with the expression of the output voltage as in equation-2.

The expression for the output voltage V_o in terms of input voltages V_{in} is given as:

$$V_o = -sCRV_{in}, \tag{2}$$

when $V_p = V_n = 0$.

B.2. ***Voltage-Mode Integrators***

Voltage- mode integrators leads to an output voltage which is proportional to the integral of the input voltage. Two types of integrator circuits exist, these are:

i) Ideal Integrator (Lossless Integrator)
ii) Non-Ideal Integrator (Lossy Integrator)

Both types of integrators behave as a first-order low pass filter which can be verified by simulation results obtained so. The circuit implementation using CCCDBA[7],[8],[9],[10] is shown in the Fig.-2 and 3 respectively along with the expressions for the output voltage for both types of integrator circuits as given by equation-4 and 6 respectively.

B.2.1. Ideal Integrator (Lossless Integrator)

CCCDBA based Ideal integrators are shown in Fig.-2 and the expression for output voltage in terms of input voltage is expressed by equation-4.

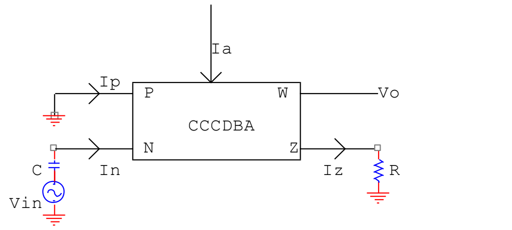

Fig. 1: Proposed voltage-mode differentiator

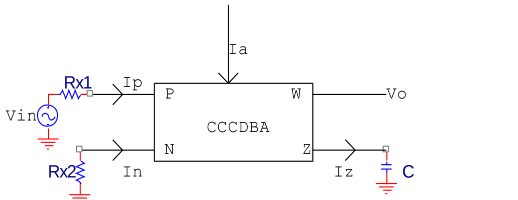

Fig. 2 : Proposed voltage-mode lossless integrator

The output voltage V_o is given as:

$$V_o.sC = \left(\frac{V_{in} - V_p}{R_{X1}}\right) + \frac{V_n}{R_{X2}} \tag{3}$$

If $V_p = V_n$ and $R_{X1} = R_{X2}$, then the transfer function of the lossless integrator becomes:

$$\frac{V_O(s)}{V_{in}(s)} = \frac{1}{sCR_{X1}} \tag{4}$$

where, $R_{X1} = R_{X2} = V_T/2I_A$

An inverting integrator can also be obtained by changing input terminals (n to p).

B.2.2. Non-Ideal Integrator (Lossy Integrator)

The circuit is shown in Fig.-4 and the expression for output voltage in terms of input voltage is given as in equation-6.

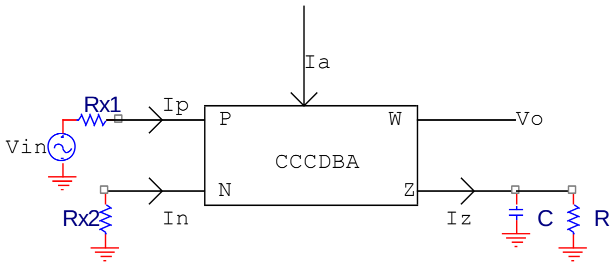

Fig. 3: Proposed voltage-mode lossy integrator

The output voltage V_o is given as:

$$V_o\left(sC + \frac{1}{R}\right) = \left(\frac{V_{in} - V_p}{R_{X1}}\right) + \frac{V_n}{R_{X2}} \tag{5}$$

If $V_p = V_n$ and $R_{X1} = R_{X2}$, then the transfer function of the lossy integrator becomes:

$$\frac{V_O(s)}{V_{in}(s)} = \frac{R/R_{X1}}{1 + sCR} \tag{6}$$

where, $R_{X1} = R_{X2} = V_T/2I_A$

III. SIMULATION RESULTS

The CCCDBA based circuit of voltage-mode differentiator of Fig.-1 was simulated and their frequency response is depicted in Fig.-4. The measured value of cut-off frequency f_o = 22.646 KHz which matches well with the value of circuit components for C = 0.1μF and R = 70Ω. Thus, confirms the workability with theoretical.

The CCCDBA based circuit of voltage-mode integrator (both lossless and lossy) as shown in Fig.-2 and Fig.-3 respectively were simulated and the responses obtained are depicted in Fig.-5 and Fig.-6 respectively, the cut-off frequency for both circuits are f_o = 244.978 KHz for lossless integrator and f_o = 1.224 MHz for lossy integrator (measured values) respectively. The components values chosen for lossless integrator were C = 0.1nF and R = 6500Ω and for lossy integrator: C = 1nF and R = 130Ω.

The simulation results were obtained using a supply voltage of ±2.5V and transistor parameters as listed in Table-1.

TABLE-1: TRANSISTOR PARAMETERS [2]

PR200N PNP

RB = 163.5,IRB = 0,RBM = 12.27, RC = 25,RE = 1.5,IS = 147E – 18,EG = 1.206,XTI = 1.7, IKF = 4.718,E – 3,NF = 1,VAF = 51.8, ISE = 50.2E – 16,NE = 1.65,BR = 0.4745,IKR = 12.96E – 3 , NR = 1,VAR = 9.96,ISC = 0, NC = 2, TF =0.610E – 9,TR = 0.610E – 8, CJE = 0.36E - 12 ,VJE = 0.5, MJE = 0.28, CJC = 0.328E – 12, VJC = 0.8, MJC = 0.4 X,CJC = 0.074 ,CJS =1.39E – 12,VJS = 0.55, MJS = 0.35, FC = 0.5, XTB = 1.866, BF = 110.0

NR200N NPN

RB = 262.5, IRB = 0,RBM = 12.5, RC = 25, RE = 0.5 ,IS = 242E – 18, EG = 1.206, XTI = 2, XTB = 1.538,BF = 137.5, IKF = 13.94E – 3, NF = 1.0 ,VAF = 159.4, ISE= 72E – 16, NE = 1.713, BR = 0.7258 ,VAR = 10.73, ISC = 0 NC = 2,TF = 0.425E – 9,TR = 0.425E – 8, CJE = 0.428E –12,VJE = 0.5,MJE = 0.28, CJC = 1.97E – 13,VJC = 0.5, MJC = 0.3, XCJC = 0.065, CJS = 1.17E – 12,VJS = 0.64,MJS = 0.4 FC=0.5

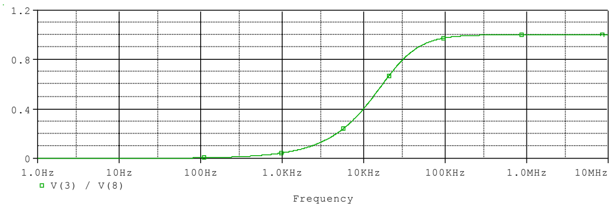

Fig. 4: Response of voltage-mode differentiator for ac input (response of a first-order highpass filter)

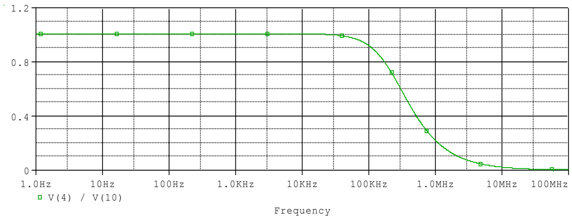

Fig. 5: Response of voltage-mode lossless integrator for ac input (response of first order lowpass filter)

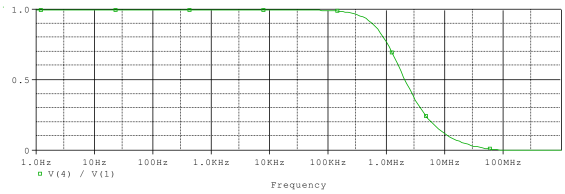

Fig. 6: Response of voltage-mode lossy integrator for ac input (response of first order lowpass filter)

D. CONCLUSION

The voltage-mode building blocks of differentiators and integrators (both lossy and lossless) have been presented which can be used to form active filters. These building blocks are quite helpful in the realization of active filters for frequencies of more than 1.0MHz. and these filters operate for voltage as low as 2.5V or less.

The frequency of these filters can be easily and widely controlled by a single DC bias current and this provides good tunability. All the circuits were tested using SPICE and the verified results confirms the theoretical values.

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