

Design of CCCDBA Based Voltage Mode Differentiator and Integrator

Vishal Ramola¹

Saurabh Mishra²

¹ Assistant Professor, Department of Electronics and Communication Engineering

¹ Assistant Professor, Department of Electronics and Communication Engineering

Uttarakhand Technical University, Dehradun, Uttarakhand, India

Graphic Era University, Dehradun, Uttarakhand, India,

R.K. Singh³

D.S. Chauhan⁴

³Professor, Department of Electronics and Communication Engineering, Kumaon Engineering College, Dwarahat, Almora, Uttarakhand, India

⁴Vice chancellor, Uttarakhand Technical University, Dehradun, Uttarakhand, India

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)

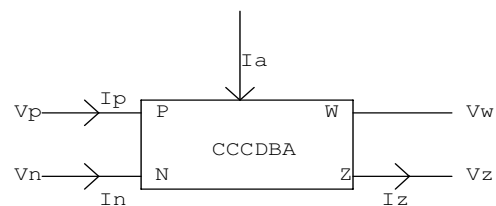


Fig. 1: Symbolic representation of current-controlled CDBA [7],[8]

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.

$$\begin{bmatrix} v_p \\ v_n \\ i_z \\ v_w \end{bmatrix} = \begin{bmatrix} 0 & 0 & R_x & 0 \\ 0 & 0 & 0 & R_x \\ 0 & 0 & 1 & -1 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} v_z \\ i_z \\ i_p \\ i_n \end{bmatrix} \quad (1)$$

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.

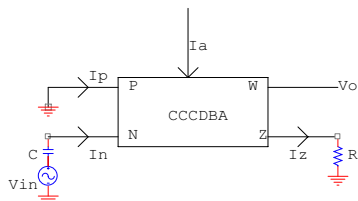


Fig. 1: Proposed voltage-mode differentiator

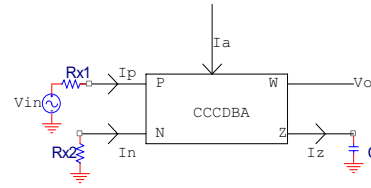


Fig. 2 : Proposed voltage-mode lossless integrator

The output voltage V_o is given as:

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

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.

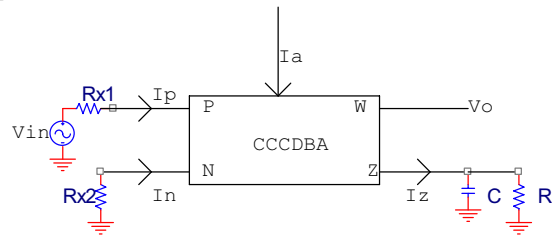


Fig. 3: Proposed voltage-mode lossy integrator

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 $C = 0.1\mu F$ and $R = 70\Omega$. 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 $f_0 = 244.978$ KHz for lossless integrator and $f_0 = 1.224$ MHz for lossy integrator (measured values) respectively. The components values chosen for lossless integrator were $C = 0.1nF$ and $R = 6500\Omega$ and for lossy integrator: $C = 1nF$ and $R = 130\Omega$.

The simulation results were obtained using a supply voltage of $\pm 2.5V$ 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

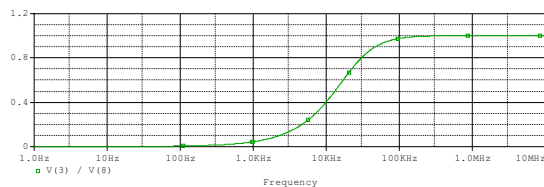


Fig. 4: Response of voltage-mode differentiator for ac input (response of a first-order highpass filter)

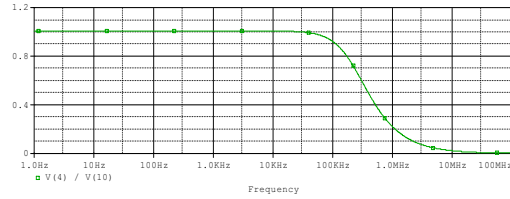


Fig. 5: Response of voltage-mode lossless integrator for ac input (response of first order lowpass filter)

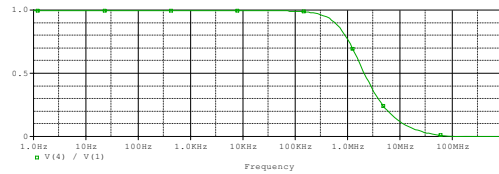


Fig. 6: Response of voltage-mode lossy integrator for ac input (response of first order lowpass filter)

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.

REFERENCES

[1] Akerberg D. and Mossberg K., “A Versatile Building Block: Current Differencing Buffered Amplifier Suitable for Analog Signal Processing Filters”, *IEEE Trans.Circuit Syst.CAS-21*, , pp.75-78,(1974).

[2] Frey D. R., “Log-domain filtering: an approach to current-mode Filtering”, *IEEE Proceedings*, Pt. G., Vol.140, pp. 406-416, (1993).

[3] Jaikala, W. Sooksood. K., and Montree. S., “Current-Controlled CDBA’s (CCCDBA’s) based Novel current-mode universal biquadratic filter”, *IEEE Trans., ISCAS 2006*, pp. 3806-3809, (2006).

[4] Keskin, A.U. and Hancioglu, E., “CDBA-based synthetic floating inductance circuits with electronic tuning properties”, *ETRI Journal*, Vol.27, No.2, pp. 239-242,(2005).

[5] Maheshwari S. and Khan I.A. , “Current controlled current differencing buffered amplifier: implementation and applications,” *Active and Passive Electronics Components*, Vol.27, No.4, pp.219-222(2004),.

[6] Maheshwari S., “Voltage-Mode All-Pass filters including minimum component count circuits”, *Active and Passive Electronic Components*, vol. 2007, pp. 1-5(2007).

[7] Sumaytee Pisitchalermping, Danucha Prasertsom, Thanawat Piyatat, Worapong Tangsrirat and Wanlop Surakamponorn, “ current tunable quadrature oscillator using only CCCDBAs and grounded capacitor” , *ECTI-con 2007 The 2007 ECTI international conference*, pp.32-35, (2007)

- [8] Tangsriat, W. Surakampontron W. and Fujii, N., "Realization of Leapfrog Filters Using Current Differential Buffered Amplifiers", *IEICE Trans. Fundamental.*, vol. E86-A, No.2, pp. 318-326, (2002).
- [9] Tangsriat W and Surakampontron W., "Electronically tunable floating inductance simulation based on Current-Controlled Current Differencing Buffered Amplifiers", *Thammasat Int. J. Sc. Tech.*, vol. 11, no. 1, pp. 60-65, (2006).
- [10] Tangsriat W. and Surakampontron W., "Realization of multiple-output biquadratic filters using current differencing buffered amplifier," *International Journal of Electronics*, vol.92,No.6,pp.313-325, (1993).
- [11] Toker A., Ozouguz S., and Acar C., "Current-mode KHN-equivalent biquad using CDBAs", *Electronics Letters.*, Vol. 35, No. 20, pp. 1682-1683, (1999).
- [12] Worapong Tangsriat, " Novel minimum-component universal filter and quadrature oscillator with electronic tuning property based on CCCDBAs" , *Indian Journal of pure and applied physics*, Vol. 47, pp. 815-822, (Nov 2009).
- [13] Worapong Tangsriat and Wanlop Surakampontron, " Electronically tunable quadrature oscillator using current controlled current differencing buffered amplifiers" , *Journal of active and passive electronic devices*, Vol.4, pp. 163-174, (2009).