Realization of OTA-based CDBA

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Abstract: This paper presents the OTA-based current differencing buffered amplifier (CDBA), which has a simple configuration comprised four OTAs. The proposed circuit is ease of design and suitable for analog signal processing applications in both voltage and current modes. The first order allpass filters were implemented as the application examples in order to demonstrate the performances of the proposed CDBA. PSPICE analog simulation and the commercially available OTAs-based experimental results verifying the circuit performances are also included.

Keywords: CDBA, OTA-based circuit, CDBA-based allpass filter

1. INTRODUCTION

A current differencing buffered amplifier (CDBA) has been first introduced in 1999 [1]. It is defined as a new versatile two-port active element represented symbolically as shown in Fig. 1. The port relations can be characterized by the following equations:

$$V_p = V_n = 0\,,\ I_z = I_p - I_n\,,\ V_z = V_w \tag{1}$$

Fig. 1 and Eq. (1) show that its input-port consists of p-terminal and n-terminal, which has the zero input voltages. The two terminals of its output-port are assigned as w-terminal and z-terminal. The current through z-terminal follows the difference of the currents through p-terminal and n-terminal. The difference of the input currents I_p and I_n is transferred to z-terminal, whereas the voltage of w-terminal follows the voltage of z-terminal. Moreover, the difference of the input currents is converted into the output voltage V_w though the impedance, which will be connected to z-terminal. Therefore, the CDBA can be considered as a transimpedance amplifier.

All the advantages of CDBA such as the differential nature at its input-port, high-slew rate, and wide bandwidth make this element especially suitable for both current and voltage modes filter implementations [2]-[5]. Therefore, the purpose of this paper is to present a monolithic integrated technique for realization of high performances CDBA and to offer new opportunities for analog circuit designers same as the approach in [6]. This approach employs two second generation current conveyors (CCIIs) and a voltage buffer. However, we develop this idea in the difference way to realize the alternative CDBA using the operational transconductance amplifiers (OTAs). This is due to the fact that the OTAs are the low-cost and electronically tunable characteristic devices.

The purpose of this paper is to present the realization of OTA-based CDBA. In order to demonstrate the performances of the proposed realization, the first order allpass filters were implemented as the application examples. PSPICE simulation and experimental results verifying the characteristics of the proposed CDBA are agreed with the theoretical value.

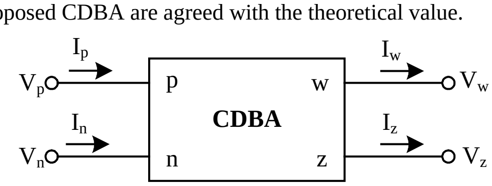

Fig. 1 Circuit symbol of CDBA

2. CIRCUIT DESCRIPTION

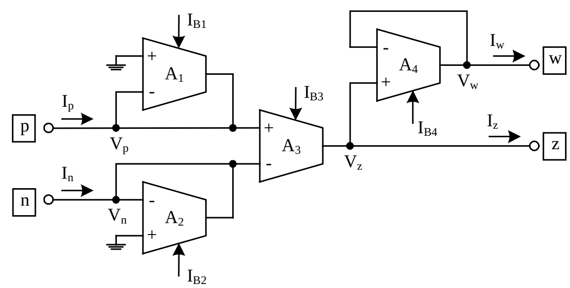

Fig. 2 Proposed realization of CDBA

The proposed realization of CDBA as shown in Fig. 2 comprises of four OTAs with closely matched characteristics. The relations between the input voltages and currents at p-terminal and n-terminal can be stated as

$$V_p = \frac{I_p}{g_{m1}} \tag{2}$$

$$V_n = \frac{I_n}{g_{m2}} \tag{3}$$

The transconductance gain g_{mi} of the OTA A_i is equal to $I_{Bi}/2V_T$. Where I_{Bi} and V_T are the external bias current of the OTA A_i and the thermal voltage, respectively.

Considering at the unity-gain feedback OTAs A_1, A_2, and A_4, if their transconductance gains are set to the high values. Then theses OTAs will act as the impedance voltage follower [7] for the input voltages as following equation:

$$V_p = V_n = 0 \tag{4}$$

$$V_z = V_w \tag{5}$$

Considering at z-terminal, the current I_z can be given by

$$I_z = g_{m3}\left(V_p - V_n\right) \tag{6}$$

Substituting Eqs. (2)~(3) into Eq. (6) the output current I_z can be written as

$$I_z = g_{m3}\left(\frac{I_p}{g_{m1}} - \frac{I_n}{g_{m2}}\right) \tag{7}$$

From Eq. (7), if we design $g_{m1} = g_{m2} = g_{m3}$, the output current I_z can be rewritten as

$$I_z = I_p - I_n \tag{8}$$

It is clearly seen that the proposed circuit in Fig. 2 similarly functions as the CDBA referred in Eq. (1).

3. RESULTS AND APPLICATION EXAMPLES

3.1 Simulation results and Application examples

The performances of the proposed circuit were studied by the use of PSPICE analog simulation program. The simulation results were carried out using commercial OTA model as LM13600N. The power supply voltages are set to $\pm$ 10V. The bias current of the OTAs I_{B1}, I_{B2}, I_{B3}, and I_{B4} are set to 1mA.

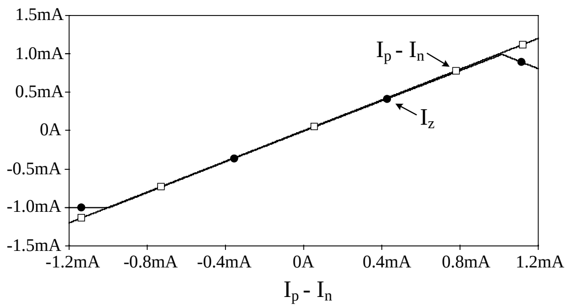

Fig. 3 Simulated current transfer characteristic

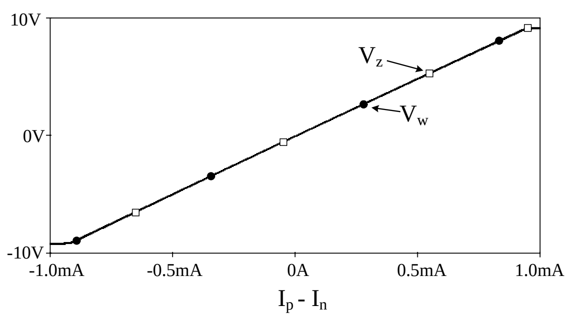

Fig. 4 Simulated voltage transfer characteristic

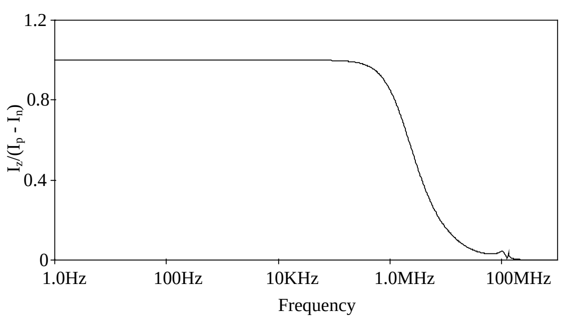

Fig. 5 Simulated frequency response of the current transfer characteristic

The simulation results of the transfer characteristics as mentioned in Eq. (8) and Eq. (5) are shown in Fig. 3 and Fig. 4, respectively. Where the input current I_n is set to zero and the input current I_p is varied from -1.2mA to 1.2mA. The resistances connected at z-terminal are set to 1kΩ and 10kΩ for the results as shown in Fig. 3 and Fig. 4, respectively.

Fig. 3 shows that the difference of the input currents I_p and I_n is linearity transferred to z-terminal over entire the current-dynamic range, which depends on the external bias currents of the OTAs. Fig. 4 shows the linear voltage transfer characteristic from z-terminal to w-terminal over entire the voltage-dynamic range, which is depended on the power supply voltages.

From the comparison result of the simulated frequency responses between the current and voltage transfer characteristics of the proposed CDBA, the bandwidth response of the voltage transfer characteristic is wider. Thus in this paper shows only the frequency response of the current transfer characteristic in Fig. 5. The bandwidth of about 1.66MHz is observed.

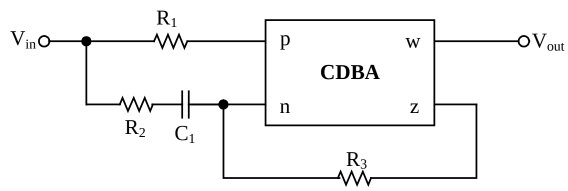

Fig. 6 Voltage-mode first order allpass filter

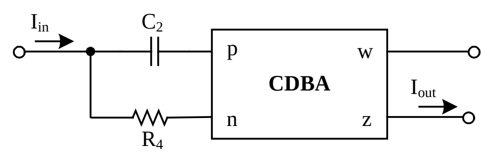

Fig. 7 Current-mode first order allpass filter

As the application examples of the proposed CDBA, the voltage and current modes first order allpass filters as shown in Fig. 6 [8] and Fig. 7 [9] were simulated. The allpass filter passes all frequencies with equal gain. The only requirement is that its amplitude response be constant. Normally, this constant is equal to 1. From the circuit configurations as shown in Fig. 6 and Fig. 7, the transfer functions of the first order allpass filters can be stated as

$$\frac{V_{\text{out}}(s)}{V_{\text{in}}(s)} = \frac{R_3}{2R_1}\frac{1 - sC_1(R_1 - R_2)}{1 + sC_1R_2} \tag{9}$$

$$\frac{I_{\text{out}}(s)}{I_{\text{in}}(s)} = -\frac{1 - sC_2R_4}{1 + sC_2R_4} \tag{10}$$

Based on Eq. (9), if we design the unity-gain allpass filter, the conditions $R_1 = 2R_2$ and $R_3 = 4R_2$ are required.

For the voltage-mode first order allpass filter as shown in Fig. 6, the passive elements are chosen as R_1 = 20kΩ, R_2 = 10kΩ, R_3 = 40kΩ, and C_1 = 1nF. Fig. 8 and Fig. 9 show the simulation results of the voltage-mode first order allpass filter. The simulated responses of the current-mode first order allpass filter are shown in Fig. 10 and Fig. 11, where R_4 = 10kΩ and C_2 = 10nF.

It is evident that both of voltage and current modes first order allpass filters using the proposed CDBA are agreed with the theoretical values.

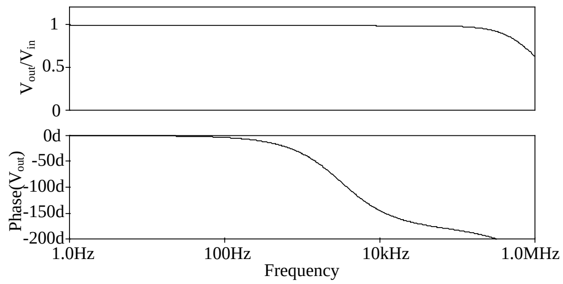

Fig. 8 Gain and phase responses of the allpass filter in Fig. 6

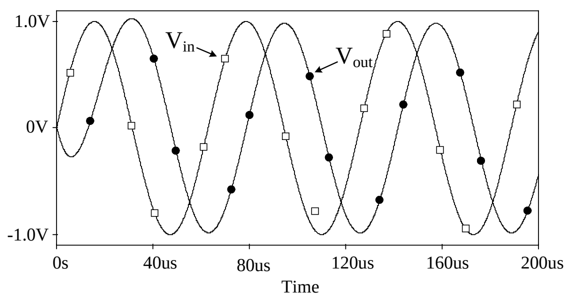

Fig. 9 Simulated response of the allpass filter in Fig. 6

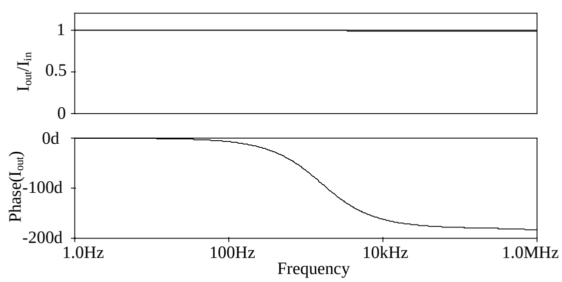

Fig. 10 Gain and phase responses of the allpass filter in Fig. 7

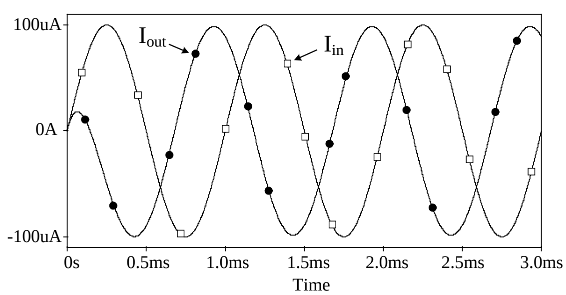

Fig. 11 Simulated response of the allpass filter in Fig. 7

3.2 Experimental results

To verify the performances of the proposed CDBA, the voltage and current modes first order allpass filters as shown in Fig. 6 and Fig. 7 were implemented using the dual variable OTAs LM13600N with the same circuit parameters used in PSPICE simulation.

The experimental results of the voltage and current modes of first order allpass filter are shown in Fig. 12, and Fig. 13, respectively. It can be seen that the proposed CDBA is suitable to offer new opportunities for analog circuit designers such as allpass filters.

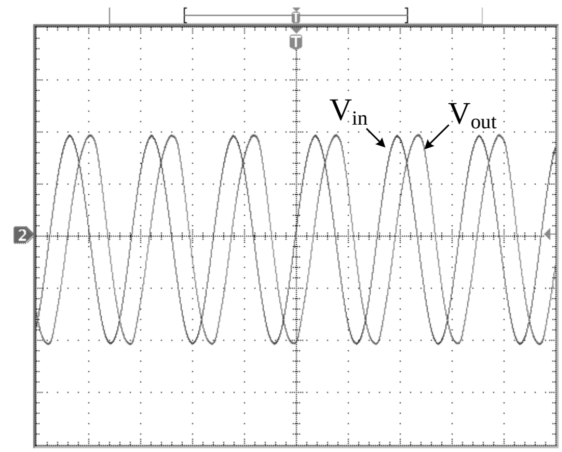

Fig. 12 Experimental response of the allpass filter in Fig. 6 (vertical scale: 0.5V/div, horizontal scale: 40us/div)

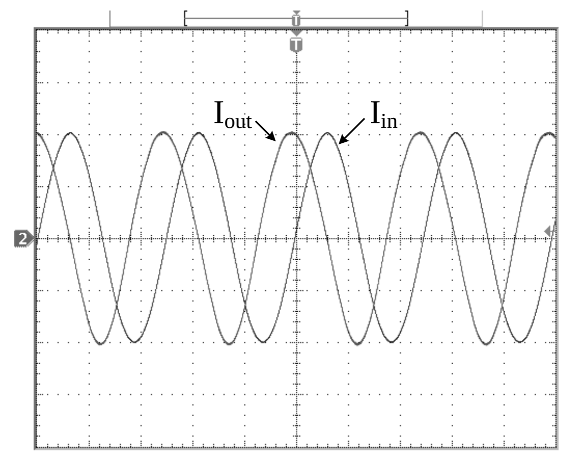

Fig. 13 Experimental response of the allpass filter in Fig. 7 (vertical scale: 50uA/div, horizontal scale: 400us/div)

4. CONCLUSITON

The realization of CDBA using four OTAs has been presented. The basic performances of the proposed circuit are confirmed by PSPICE simulation and experimental results. The current and voltage transfer characteristics are linear and wide dynamic ranges. The feasibility of the circuit has been tested on the voltage and current modes allpass filters.

REFERENCES

[1] C. Acar and S. Ozoguz, “A new versatile building block: current differencing buffered amplifier suitable for analog signal processing filters”, *Microelectronics J.*, Vol. 30, pp. 157-160, 1999.

[2] S. Ozouguz, A. Toker and C. Acar, “Current-mode continuous-time fully integrated universal filter using CDBAs”, *Electronics Letters*, Vol. 35, No. 2, pp. 97-98, Jan. 1999.

[3] A. Toker, S. Ozouguz and C. Acar, “Current-mode KHN-equivalent biquad using CDBAs”, *Electronics Letters*, Vol. 35, No. 20, pp. 1682-1683, Sep. 1999.

[4] Worapong Tangsrirat, Nobuo Fujii, Wanlop Surakamporn, “Current-mode Leapfrog ladder filters using CDBAs”, *IEEE International Symposium on*

Circuits and Systems, ISCAS 2002, Vol. 5, pp. 57-60, May 2002.

[5] Khaled Salama, Serdar Ozoguz and Ahmed Soliman, "A New Universal Biquad using CDBAs", *Proc. of the 44th IEEE 2001 Midwest Symposium on Circuits and Systems, MWSCAS2001*, Vol. 2, pp. 850-853, Aug. 2001.

[6] Nil Tarim and Hakan Kuntman, "A High Performance Current Differencing Buffered Amplifier", *The 13th International Conference on Microelectronics*, pp. 153-156, Oct. 2001.

[7] W. Surakampontorn, V. Riewruja, C. Surawapunya, S. Yodladda, "Instrumentation amplifier using operational transconductance amplifiers, *Int; J. Electronics*, Vol. 71, No. 3, pp. 511-515, 1991

[8] S. Ozcan, H. Kuntman, A. Toker, O_uzhan Ciceko_lu, "CDBA akif elemati kullanilarak gercekle_tirilen tum geciren filterer", P*roc. Of the National Electrical-Electronics-Computer Engineering Symposium, ELECO'2000*, pp. 33-37, Bursa, Turkey, 2000.

[9] Ali Toker, Serdar Ozoguz, Oguzhan Cicekoglu, and Cevdet Acar, "Current-Mode All-pass Filters Using Current Differencing Buffered Amplifier and a New High-Q Bandpass Filter Configuration", *IEEE Transc. On Circuit and Systems-II: Analog and Digital Signal Processing*, Vol. 47, No. 9, Sep. 2000.