CDBA - Current Based Instrumentation Amplifier

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***Abstract*— This paper presents a novel method to realize a current mode instrumentation amplifier (CMIA) through CDBA (Current difference Buffered Amplifier). It employs two CDBAs and two resistors to obtain desired functionality. Further, it does not require any resistor matching. The gain can be set according to the resistor values. It offers high differential gain and a bandwidth, which is independent of gain. The working of the circuit is verified through PSPICE simulations using CFOA IC based CDBA realization.**

Keywords—CDBA; CMIA; current gain; slew rate; parasitic capacitance.

I. Introduction

Instrumentation Amplifiers (IA) are used in many application areas, such as medical instrumentation, the read-out circuit of biosensors, bio-medical detection [1], neural signal sensing [2], signal processing, and data acquisition [3]. IAs are able to resolve the issues of finite input resistance and limited gain of differential amplifiers [4]. They are able to amplify low level signals [1].The IA can be designed using conventional voltage mode op-amps, however, these IA suffer from the limitations of producing errors at higher frequencies due to lower slew rate and constant gain-bandwidth product [5].

The available IAs are classified according to the active block used. However, a general classification can be done on the basis of the type of signal being processed and the output made available. Considering this, available IAs are classified as voltage mode (VM), transadmittance mode (TAM), transimpedance mode (TIM) and current mode (CM). In this context, nomenclature VM and TAM are assigned to the structure processing voltage input and providing output as voltage and current. Similarly, TIM and CM accept current input and provide a voltage and current at the output. Voltage mode (VM) IA requires precise resistor matching condition to achieve high common-mode rejection ratio (CMRR) [1, 6].

Since, the last few decades, current mode technique [1-3, 6-18] has gained a lot of importance due to its benefits, such as larger dynamic range, greater linearity, lower power consumption and simplicity in circuit design [19], over voltage mode counterpart. The current mode active blocks are also able to provide higher slew rate and thus able of operating at higher frequencies. In literature, a variety of active blocks, namely OP-Amp, CCII (Second generation current conveyor), OTA (Operational transconductance amplifier), EOTA (Electronically and linearly tunable OTA), CDTA (Current differencing transconductance amplifier), OTRA (Operational transresistance amplifier), OFCC (Operational floating current conveyor), DVCC (Differential voltage current conveyor), CCCCTA (Current controlled current conveyor transconductance amplifier), CFOA (Current feedback operational amplifier) etc.have been used to develop IAs.

Most of the work available on VMIA [1-3, 6, 7, 9, 10, 12-14, 16, 17], TAM [3] and TIM [18]; and only one active block based CMIA [20] is available to the best of author's knowledge that has been realized with DO-CCII. It has resistor matching constraint and is realized using two grounded resistors. Also, it provides high output impedance current.

Current differencing buffered amplifier (CDBA), a versatile active building block, has been introduced in [21]. It inherits the advantageous features of current mode technique. It is free from parasitic capacitances, hence, is suitable for high frequency operation [5]. It can be operated in both voltage and current mode, thereby allowing more flexibility to the circuit designers. An extensive literature survey suggests that in recent past CDBA has been extensively used for realizing a number of analog signal processing applications, mainly filters, oscillators, inverse filters and multivibrators [5, 19, 21-36]. It has been found that no instrumentation amplifier using CDBA has yet been designed.

This paper aims at filling this gap and proposes a CMIA based on CDBA. The proposed configuration comprises of two CDBA and two resistances. It imposes no resistor matching constraint on resistors, low impedance current input and high impedance current output. The behavior of the proposed CMIA is examined in the presence of non-idealities. SPICE simulation results are included to verify the performance of the proposed CMIA.

II. Circuit Description

The CDBA is a four terminal device and is represented by the block diagram of Fig. 1. It has two low impedance current input terminals p and n, and provides current output at the high impedance z terminal. The voltage of z terminal is conveyed to w terminal. The terminal characteristics are given in (1)

$$I_z = I_p - I_n;\ V_w = V_z;\ V_p = V_n = 0 \qquad (1)$$

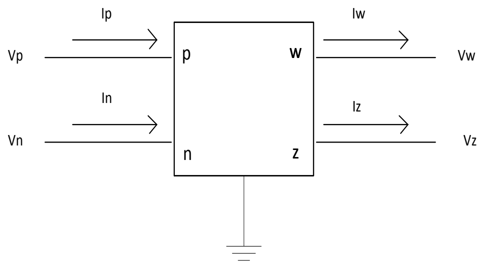

Fig. 1. Block diagram representation of CDBA.

The CDBA can be realized using commercially available IC AD844 [37] as shown in schematic of Fig. 2.

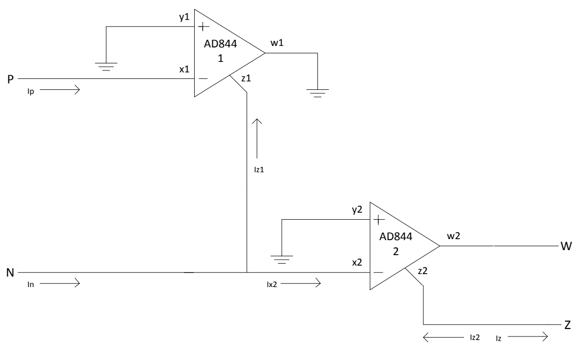

Fig. 2. Schematic of CFOA based CDBA.

Ideally, the input impedance at the x terminal is zero and the output resistance is infinite at the z-terminal. Input terminals of CDBA are virtually grounded. The current flowing out from z-terminal is equal to the difference of currents flowing into p and n terminals and the voltage at w-terminal follows the voltage at z-terminal.

III. Proposed Circuit

The proposed CDBA based CMIA is shown in Fig. 3. It uses two CDBAs and two resistors. As CDBA's input impedance is low and output impedance at z terminal possesses high impedance, the output can be directly used. Therefore, it does not require any impedance matching circuitry.

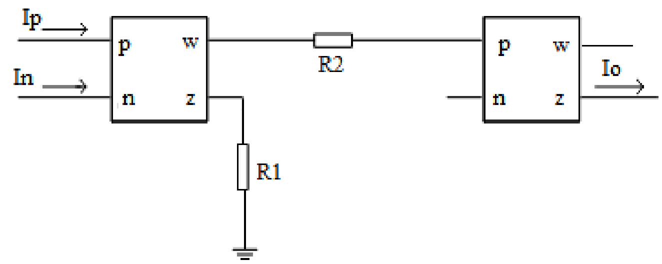

Fig. 3. Circuit Diagram for current Instrumentation amplifier.

The differential current gain of the proposed IA is computed as

$$A_d = \frac{I_o}{I_p - I_n} = \frac{R_1}{R_2} \qquad (2)$$

It is clear that A_d can be easily varied by varying the values of R_1 and R_2.Hence, no resistor matching is required.

IV. Non Ideality Analysis

In the analysis so far, ideal characteristics of CDBA have been considered. For the proposed circuit, CDBA was realized using CFOA IC (AD844) as shown in Fig. 2.

In this section we will investigate the effect of the non-idealities of CFOA by considering the practical model of the CDBA. The structure of the CDBA, which uses a practical model of AD844, is shown in Fig. 4. It consists of parasitic capacitances and resistances at y is R_y and C_y and at z is R_z in parallel of C_z, terminals, terminals of AD844 and a finite input resistance R_x at port x. It may be noted that the y terminal of AD844 are grounded therefore the performance remains unaffected by their presence. For the AD844, the input resistance Rx=50 KΩ and Rz=3 MΩ.

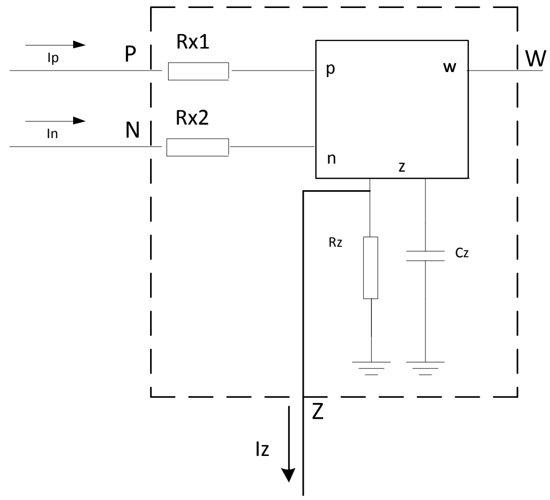

Fig. 4. Non ideal structure of CDBA

Fig. 4 shows the block diagram representation of non-ideal CDBA. The equivalent circuit of CDBA made with AD844 can be approximated to the ideal model if the external resistance at the input terminal of CDBA is much larger than R_x and $R_z >> R_x$.

CDBA circuit, shown in Fig. 4, when substituted in the proposed structure of Fig. 3 results in non-ideal circuit of the proposed CMIA as shown in Fig. 5.

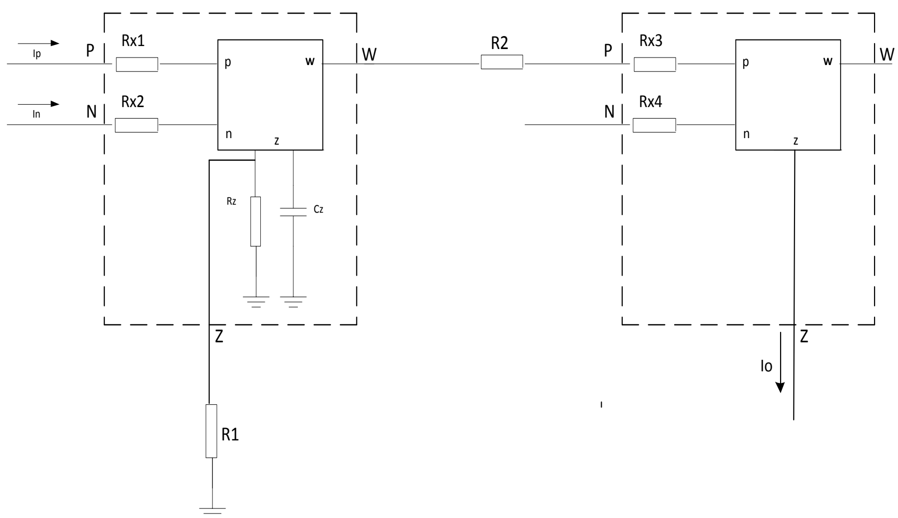

Fig. 5. Non-ideal structure of the proposed CMIA.

For the equivalent circuit of proposed CMIA, the following parameters of the proposed circuit get modified:-

- Output current,

$$Io(s) = \frac{1}{G_1^{'} + sC_Z} \cdot \frac{1}{R_2 + R_{X3}} \cdot (I_P - I_N) \qquad (3)$$

where,

$$G_1^{'} = \frac{1}{R_1 \parallel \mathrm{R}_Z}$$

- Differential gain,

$$A_D(s) = \frac{1}{G_1^{'} + sC_Z} \cdot \frac{1}{R_2 + R_{X3}}. \qquad (4)$$

Choosing $R_2 >> R_{x3}$, the effect of R_{x3} can be accommodated. Further it may be seen that $A_D(s)$ has a pole at G_1'/C_Z, so the CMIA will be working correctly for signals having frequency much below G_1'/C_Z. Also Common mode gain tends to zero for these conditions.

V. SIMULATION RESULTS

The functionality of proposed CMIA is verified through SPICE simulation using CFOA based CDBA realization. The simulated responses for differential gain and common mode gain are shown in Fig. 6 and Fig. 7 respectively. The resistance R_2 is taken as 2 KΩ and R_1 can be chosen as 20 KΩ to obtain differential gain of 10 A/A. The corresponding simulated differential gains are obtained as 9.6 A/A. The deviation between simulated and theoretical gains may be attributed to the non-idealities of CDBA. Further, it may be noted from Fig. 6 that common mode signal is significantly attenuated thereby indicating high CMRR.

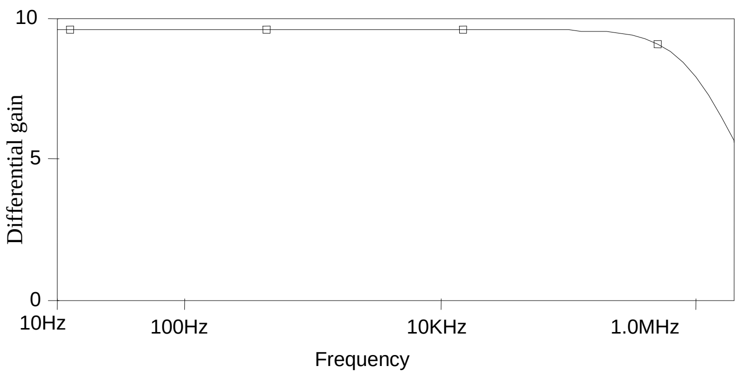

Fig. 6. Simulated response for differential input.

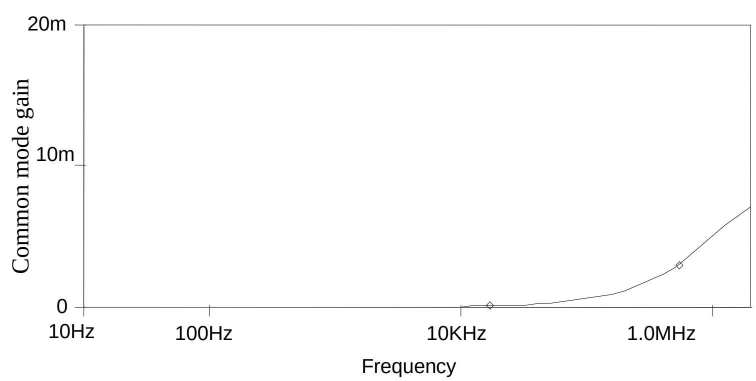

Fig. 7. Simulated response for common mode signal.

VI. CONCLUSION

A CDBA-based CMIA is presented which can process current signals directly. The proposed circuit, to the best knowledge of the authors, is the only CDBA-based current amplifier, with low input impedance, high output impedance and no requirement of resistor matching. The simulations are performed with AD844 IC. Simulation outputs verify the theoretical propositions.

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