Design of current controlled instrumental amplifier by using complementary metallic oxide semiconductor technology

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Article Info

ABSTRACT

In this paper, a complementary metal oxide semiconductor (CMOS) instrumental amplifier was designed and implemented in order to provide the possibility of controlling the current and voltage gain. The proposed instrumentation amplifier consists of three conveyors with active resistor. The parasitic resistance value (Rx) was reduced with a large bandwidth level in addition to achieving a high common mode rejection ratio (CMRR). Simulation was performed by using 0.35 µm CMOS technology by using the advanced design system (ADS) software. The results obtained prove that the proposed circuit has a good efficiency with higher degree of CMRR in comparison with other amplifiers designed and implemented in other similar works.

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1. INTRODUCTION

The transferring and processing of bio potential reliably considered as a basic tasks in the biomedical systems [1]. For this purpose, the instrumentation amplifiers have a wide utilizations in the analog signal processing in biomedical applications that often used in the voltage-mode as an important block [2]. Voltage-mode instrumentation amplifiers can be implemented by utilizing operational amplifiers often have a high transfer function [3]. Therefore, a main problem of such circuits is the great common-mode rejection ratio (CMRR) to the resistor mismatching [4].

The CMRR was considered as the main parameter in designing of instrumentation amplifiers. The main disadvantage of these circuits is the needed for several matching resistors to achieve a desired high level of CMRR [5]. In addition, the limitation of voltage gain that produced by voltage-mode amplifiers is dependent on the gain-bandwidth parameter [6]. On the side, in current-mode of these amplifiers, the CMRR is independent of the resistor mismatching, while, the voltage gain is not limited by the gain-bandwidth [7].

Currently the second generation vector current (CCII) is becoming popular because it can be used to obtain good electronic tuning and very wide operating frequency in the most applications in high frequency analog signals [8]. CCII can be used as main parameter of servomotors, oscillators and other current mode applications [9]. The parasitic resistance that appears in circuits for the mentioned current carriers is one of the defects of electronic circuits [10]. On the other hand, it is needed in transmission circuits which are current controlled because it can be controlled by bias current [11]. It is directly proportional to the surface mobility value (μ), the oxide amplitude level (Cox), as well as the relationship to channel length and width (W/L) in the so-called complementary metallic oxide semiconductor (CMOS) technique [12].

In some literature, topologies using the CCII technique have been studied and presented. For example, the design and implementation of an amplifier that is based on current carriers was presented in 1989 by Erkan *et al.* [13] who proposed 4 instrumentation amplifier topologies, one is current-mode and the other three are voltage-mode based on the current feedback operational amplifier. Some models of CCIIs based on the principle of amplification in current mode with passive resistors were announced [14]. These designs often contain passive components as well as low bandwidth which required some specifications which led to some increasing in the fabrication costs [15]. Circuits that used for the processing of biomedical signals must have a higher safety level with the attenuation ability of the interfering signal [16]. Therefore, the implementation of high-performance circuit, such as analog filters or low noise amplifiers, are needed in order of improving the system performance [17]. For the implementation of bio medical systems, some of important considerations are needed such as current levels and low noise voltage, low harmonic distortion [18].

Amplifying devices (AI) are widely used in industrial applications and in low voltage medical applications. The low and high voltage signals must be driven by common mode voltage and direct current. The traditional instrument amplifier is shown in Figure 1 [19]. The objective of this paper will focus on the design and implementation of a CMOS current mode instrumentation amplifier in order to provide the possibility of controlling the current and voltage gain for biomedical applications.
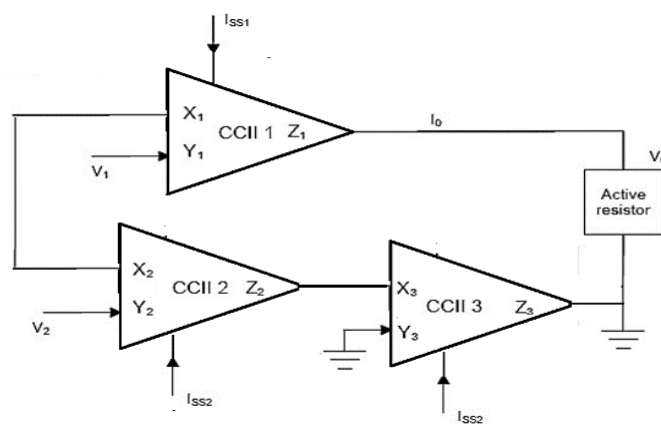

Figure 1. Traditional instrumentation amplifier

2. METHOD

The wiring diagram of the proposed device is shown in Figure 2. The proposed instrumentation amplifier consists of three current conveyors with active resistor based on CMOS technology. These amplifiers are often used to remove unwanted noise and amplify the signal in order to adapt it to the desired signal [20]. Also, the common mode rejection ratio (CMRR) is the most important parameter for instrument amplifiers. Today, there are still many ongoing physical processes for human survival. The instrument is the foundation of several electromyography (EMG) systems [21].
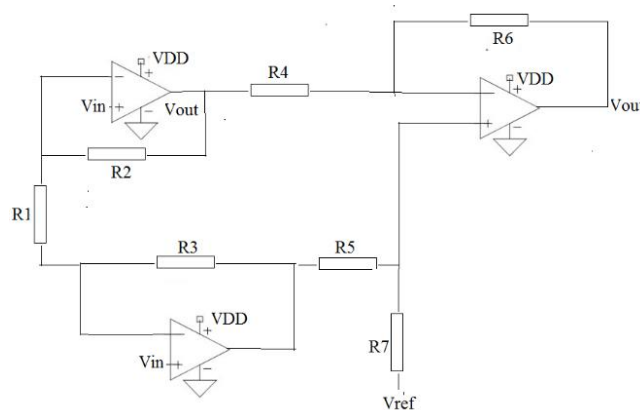

Figure 2. The proposed instrumental amplifier

Figure 3 illustrates the steps of biomedical signal processing, which pass through an electrode, amplifier, low-pass filter, sample and Hold and analog-to-digital converter (ADC) [22]. The processing of these signals is important because they often have very low amplitude and very high noise levels. It has a low frequency range, roughly less than 1 kHz.
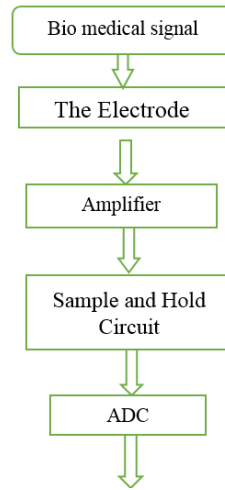

Figure 3. Steps of physiological signal processing

The current of each transistor drain can be calculated by using [23]:

$$I_{D1} = \mu_n C_{0x} \frac{W}{L} \left\{ (V_A - V_{th})V_A - \frac{V_A^2}{2} \right\} \tag{1}$$

$$I_{D1} = \mu_n C_{0x} \frac{W}{L} \left\{ (V_C - V_{th})V_A - \frac{V_A^2}{2} \right\} \tag{2}$$

The active resistance R_A can be calculated as (3).

$$R_A = \frac{1}{\mu_n C_{0x} \frac{W}{L}(V_C - V_{th})} \tag{3}$$

V_C represent the adjusting voltage used to adjust the active resistance R_A. The proposed instrumentation amplifier will supplies the following current:

$$I_0 = \frac{V_1 - V_2}{R_{X1} + R_{X2} + R_{X3}} \tag{4}$$

The voltage Vx, can be calculated as (5).

$$V_{X1} = K_1 V_1, \qquad V_{X1} = K_1 V_1, \qquad V_{X1} = K_1 V_1 \tag{5}$$

when changing the bias current of the conveyors as well as the control voltage of its active resistance, we can control its differential gain. Also, the value of the parasitic resistance can be controlled by changing the value of the bias current. The error caused by tracking the current and voltage between both ports X-Z and ports X-Y can also be calculated as (6) [24].

$$\left. \begin{array}{l} \alpha = 1 - \varepsilon_I \\ K = 1 - \varepsilon_V \\ I_z = \alpha I_X \end{array} \right] \tag{6}$$

Where α and K represent current and voltage transfer gains and ε_I and ε_V represent errors transfer of current and voltage of the conveyors, respectively. Therefore, the voltage at the output will be:

$$V_0 = \frac{R_A(V_1 - V_2)}{R_{X1} + R_{X2} + R_{X3}} \tag{7}$$

3. RESULTS AND DISCUSSION

The main problem is the minimization of resister and maximization the cutoff frequency, so, the objective function (OF) can be expressed as (8) [25].

$$OF = \alpha R_x + \beta_{tci} \qquad , \; \alpha + \beta = 1 \tag{8}$$

Table 1 illustrates the dimensions of the CMOS Transistor. By using the MATLAB software program, it can be easily draw the objective function (OF). Figures 4 and 5 show the values of the OF and the parasitic resistance R_{xmin} value respectively.

Table 1. Dimensions of the CMOS transistor

Parameter	Value (μm)
Ln	0.580
Lp	0.350
Wp	36
Wn	19.76

Figure 4 shows the objective function of the amplified signal. From Figure 4, we can notice that the amplifier signal bandwidth remains at a stabile cutoff frequency value which stay constant at (1.20 GHz). Figure 5 illustrates the value of the parasitic resistance (Rxmin). From Figure 5, we can notice that the parasitic resistance (Rxmin) tends to stabilize at a value of about (458 Ω).

Figure 6 shows that the common mode rejection ratio (CMRR) which dependent on the current transfer error (ε_I) and voltage transfer error (ε_V) has a value of (183.09 dB) at a frequency of (10 Hz), which points the importance of the proposed circuit in the biomedical devices. Table 2 illustrates a comparison between a proposed current controlled and other voltage and current controlled conveyor in different studies. Table 2 illustrates the comparison results of the CMRR value between the proposed current controlled instrumental amplifier and voltage controlled instrumental amplifier design in other works.
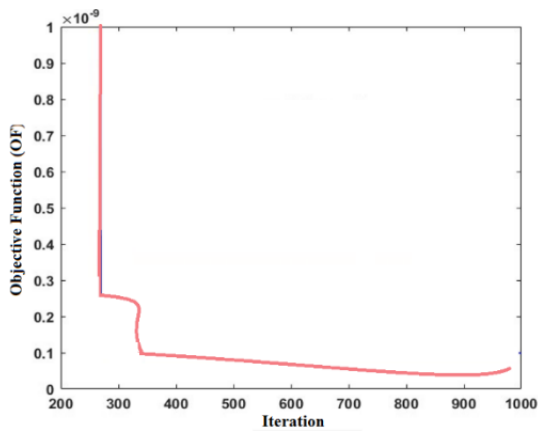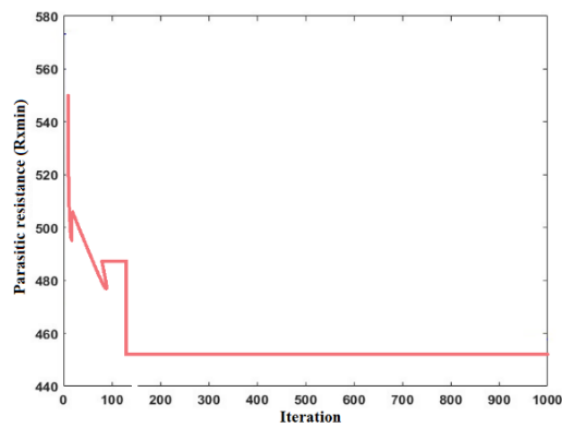

Figure 4. Objective function
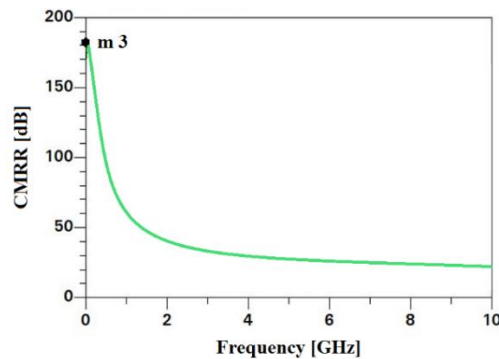

Figure 5. Result of R_{xmin}

Figure 6. CMRR simulation result

Table 2. Comparison between the proposed curren t controlled and voltage-controlled conveyor

	Voltage controlled conveyor	
	BJT [11]	CMOS [11]
Vin	2.50 V	3.30 V
CMMR	146 (dB)	143 (dB)
	Proposed current controlled conveyor	
Vin	2.80 V	3.80 V
CMMR	77 (dB)	183.09 (dB)

4. CONCLUSION

In this paper, an instrumentation amplifier design has been implemented which consists of three conveyors, suitable for applications of medical devices. The proposed amplifier circuit has been simulated by using the advanced design system (ADS) software with a parameters of (0.35 μm) CMOS technology. The obtained results indicate that the proposed amplifier is very suitable for bio-medical application. The Comparison between a proposed current controlled mode and a voltage-controlled mode implemented in other studies indicates that the proposed current controlled mode has a better CMRR value than the voltage controlled mode.

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