A High Gain and Low Noise Instrumentation Amplifier byusing Telescopic amplifier for Neural Sensing Application

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Abstract:

The neural sensing systems are multi-channel, it requires continuous observation of neurons to study the human body and to identify the sudden changes in the body which leads to seizures and unexpected deaths, in order to prevent such attacks it requires a sensing amplifier to record and study the activity. Where Instrumentation amplifier is one of the sensing amplifiers which is used for signal detection and pre-processing the signal. The conventional instrumentation amplifier provides less gain and more noise which decreases the overall system performance. It requires an additional circuit to provide high gain.In this paper, the Instrumentation amplifier is designed by using two stage operational amplifier and one telescopic operational amplifier. The first stage is two stage operational amplifier (Op-amp) followed by the telescopic amplifier. Which is used to provides high gain at the output without the need for any extra circuit. In neural sensing, the systems are multi-channel due to these multi-channels the common mode interference (CMI) will occur. The CMI is generated due to the mismatch that occurs between the shared channels. To reduce the CMI a high common mode rejection ratio (CMRR) is necessary.

The instrumentation amplifier is designed and implemented on the 180nm CMOS technology with the supply voltage of 1.8V. The designed INA has the gain of 70dB with the CMRR of 98dB and the signal to noise ratio(SNR) is 100dB.

***Keywords:* CMRR, CMI, Telescopic amplifier, Instrumentation amplifier.**

I. INTRODUCTION:

Most of the electronic systems need a minimum of one stage of amplification. Hence amplifier is often seen in the majority electronic devices. Amplifiers are frequently defined as merely a device that increases the capability of a sign. In other words, it increases the amplitude of a sign and makes it stronger than the input. Amplification isn't absolutely economical; there are forever losses, distortion and noise to handle. Thus, there are an entire load of amplifiers created, that employment best in several things. Not all amplifiers give optimum output altogether and there's continuously price factors to think about.

As the fastest growth in technology, electronics can now be found in almost every field. In the biomedical applications by using of electronics helps for better understanding of the disease. In neural application we need continuous observation of various neurons in the body, to do experiments in neuroscience the neural amplifiers are helpful, and one of the neural amplifiers is instrumentation amplifier (INA) which provides high gain and suppress the interference.

This paper is organized as follows section presents the design methodology of instrumentation amplifier. In Section III, experimental results are discussed, section IV gives the comparison between INA with pseudo differential inverter and the proposed design ,Section V presents the applications and Section VI provides the conclusion.

II. DESIGN METHODOLOGY

To obtain high gain and low noise instrumentation amplifier the telescopic amplifier is used at the last block of designing. There are various design techniques are available for INA, some of them requires common mode feedback which demands an additional circuits, some uses the chopper cancellation techniques which makes the circuit complexity. In this paper, the telescopic and operational amplifiers are required to design INA.

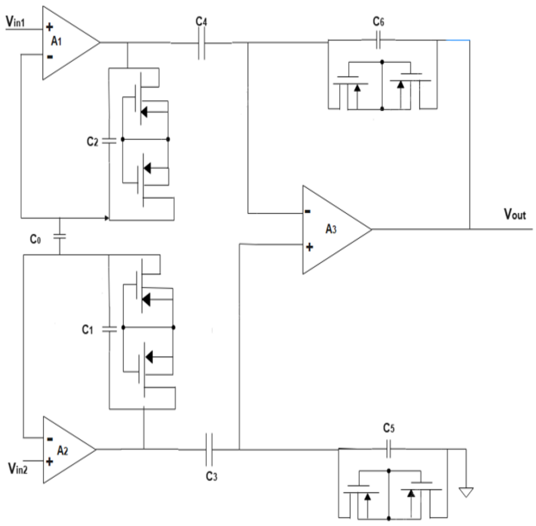

Fig. 1: Block diagram of Proposed instrumentation amplifier.

The block diagram of INA is shown in fig 1. The instrumentation amplifier has build in two stages with the help of the two stage op-amp and the telescopic op-amp.

It has two inputs and one output, the sine wave inputs are applied to the first stage of the instrumentation amplifier. The first stage is non inverting Op-amp stage the two sine wave inputs are applied to the two Op-amp's non inverting terminal and the inverting terminal of the op-amp's are designed in the feedback manner as shown in the fig 1. The output of the first stage is the amplified and given as the input of the second stage. The output of first stage is further amplified by telescopic amplifier. Generally the three op-amp design INA has resistors but in this design style the resistors are replaced with the transistors in order to reduce the terminal noise which is generated due to the resistors. C_0 to C_6 are the capacitors where C_0 is the gain deciding factor by adjusting the value of the C_0 we can adjust the gain of the circuit.

In the INA the first stage is used to amplify the strength of the weak input signal without changing it frequency and phase and the second stage here is used to provide the sufficient gain.

A. Design of Two Stage Op-Amp

The two stage Op-amp is the initial block in the designing of instrumentation amplifier, while in the designing we require two Op-amps which are non inverting op-amps.

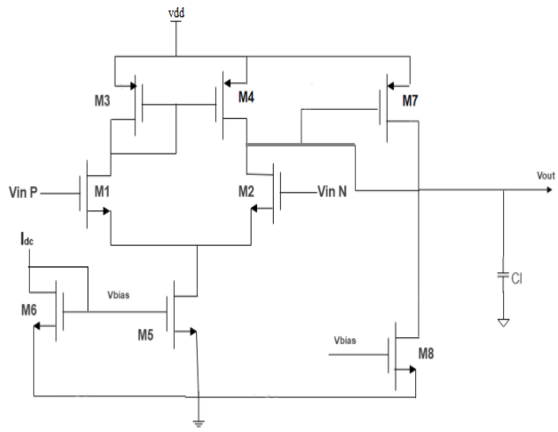

Fig. 2: Schematic of two stage Op-amp

The above shown fig 2 Op-amp is built in two stages the first stage is differential amplifier and the second stage is common source.

The basic function of this circuit is to boost and output the voltage difference between the two inputs. It is designed to be used in conjunction with other circuits to perform a wide range of operations. When it is used with an amplification circuit, an op amp can transform weak signals to strong signals. When every transistor in the circuit is operating in the saturation area, the op-amp offers significant gain (region 2). When the transistor is said to be in saturation region the following conditions to be satisfied

$$V_{GS} >= V_{TH}$$

$$V_{DS} > V_{GS} - V_{TH}$$

$$I_{DS} = \mu_n C_{OX} W/L(V_{GS} - V_{TH})^2$$

No of Transistors	Name of transistor	Length (L)	Width (W)
M1	NM0	1µ	20µ
M2	NM1	1µ	20µ
M3	NM2	1µ	30 µ
M4	NM3	1µ	10µ
M5	NM4	1µ	30 µ
M6	PM0	1µ	50µ
M7	PM1	1µ	50µ
M	PM2	1µ	19.95µ

Table. 1: W/L values for two stage Op-amp

From the fig 2 the gain of to stage Op-amp is given as

$$A_v = g_{m7} (r_{o7}//r_{08})$$

B. Design of Telescopic Amplifier

The Telescopic operational amplifier is the simplest type of op-amp. In telescopic Op-amp the transistors are placed one above the other which looks like cascode. All the transistors are appeared in the straight line in this arrangement which looks like the rails of lenses in the telescopic, hence this configuration is called as the Telescopic configuration and the amplifier designed by using this arrangement is called as the telescopic amplifier.

In the designing of the instrumentation amplifier we require the two stage telescopic Op-amp. The inputs are applied to the NMOS transistors at the first stage and the second stage is common source amplifier. The telescopic Op-amp is present in the second stage which is used to provide high gain at the final output.

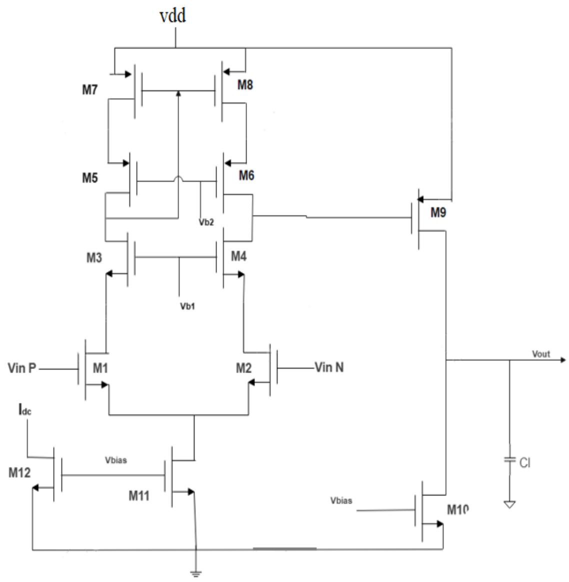

Fig. 3: Schematic of telescopic amplifier.

C. Proposed Design

The INA is designed in 180nm CMOS technology. Once the schematics are done symbols are created and arranged in the below fashion.

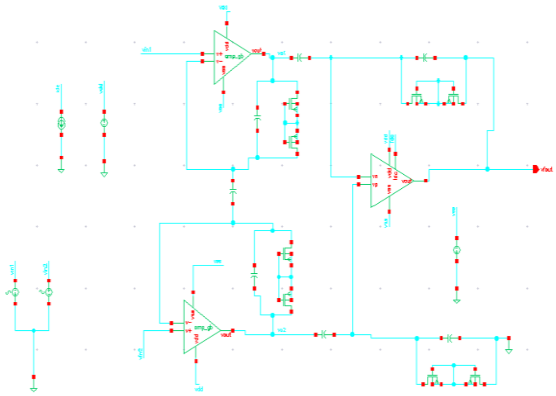

Fig. 4: Schematic of Proposed INA.

Once the differential gain is calculated from the above fig 4 the common mode gain should be calculated in order to get CMRR. To calculate the common mode gain, both the input terminals of the first stage are combined and given as a single input.

III. Experimental Results

In this section, the results of the designed circuits will be shown. The transient and ac analysis of each block will be evaluated.

i) Two stage Op-amp is designed with inputs of 10mV and 20mV with the gain of 86dB at 4Khz. The transient and ac analysis are presented in fig 8 and fig 9 respectively.

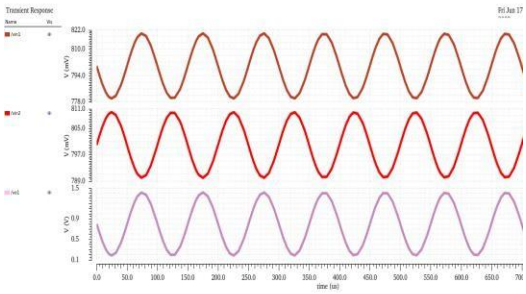

Fig. 5: Transient analysis of Two-Stage OP-AMP.

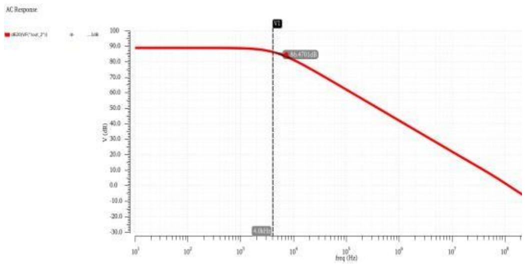

Fig. 6: Gain of Two-Stage Op-amp

ii) Telescopic amplifier is designed with inputs of 10mV and 20mV with the gain of 92dB at 3.8Khz. The transient and ac analysis are presented in fig 10 and fig 11 respectively.

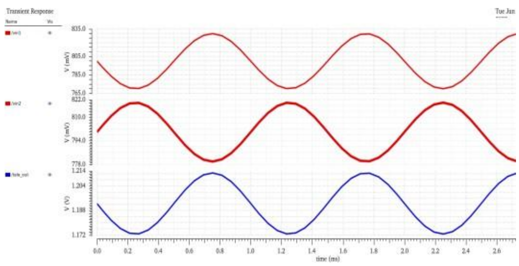

Fig. 7: Transient analysis of Telescopic Amplifier.

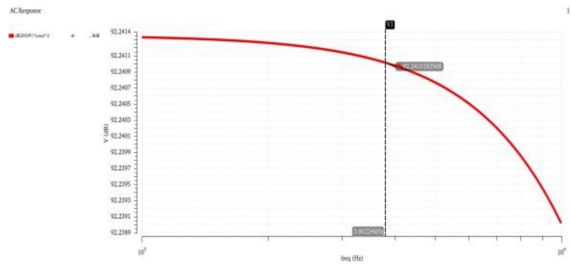

Fig. 8: Gain of Telescopic Amplifier.

iii) INA is designed with inputs of 10mV and 20mV with the gain of 70B at 6.2Khz. The transient and ac analysis are presented in fig 12 and fig 13 respectively.

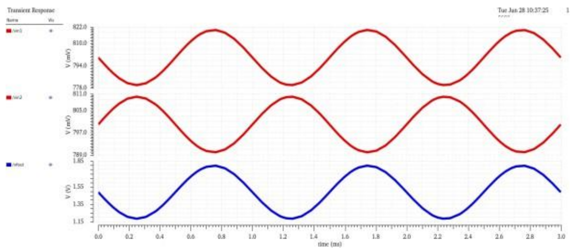

Fig. 9: Transient analysis of Instrumentation Amplifier

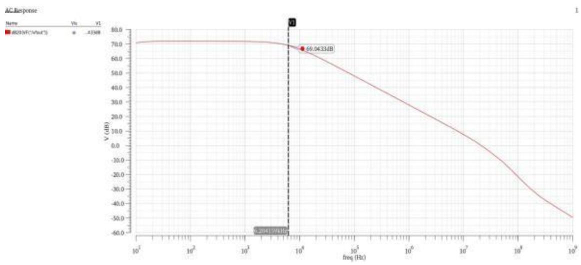

Fig. 10: Gain of an INA

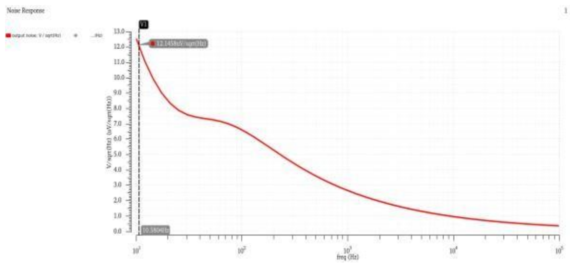

Fig. 11: Noise waveform of an INA

The noise is 12µV/sqrt(Hz).

$$CMRR = 20\log(A_d/A_c) \quad - eq1$$

$$= 20\log(5.9*10^3/75*10^{-3})$$

CMRR = 98dB

$$SNR_{dB} = 20\log_{10}(SNR) \quad - eq2$$

$= 20\log_{10}(1.27/12*10^{-6})$

SNR =100dB.

IV Comparison

Table 2, shows the comparison between the INA with pseudo differential inverter[4] and this work.

The proposed design has been implemented in 180nm CMOS technology. The operating voltage for both designs is 1.8V. The gain of proposed design is much greater and SNR is 100dB.

Parameters	INA with Pseudo differential inverter[4]	This work
Technology	180nm	180nm
Supply voltage	1.8V	1.8V
CMRR	90dB	98dB
Noise	-	12µV/sqrt(Hz)
Bandwidth	7KHz	6.2KHz
Gain	51dB	70dB
Signal to noise ratio	-	100dB

Table 2: Comparison between INA with pseudo differential inverter and proposed INA design.

V. Applications

These amplifiers are used primarily in situations where high differential gain accuracy is actually needed, strength must be maintained in noisy environments, and large common-mode signals exist.

Instrumentation amplifiers are used to acquire data from small o/p transducers such as thermocouples, strain gauges, Wheatstone bridge measurements used in the conditioning of high-speed signals for imaging and video data acquisition. INA also used in navigation, radar, and other applications

VI. Conclusion

In this paper, the instrumentation amplifier is designed. This INA is used to reduce the common mode interference noise due to the mismatch occurred between the shared reference

by increasing the CMRR. The gain of the instrumentation amplifier is also increased with the help of telescopic amplifier used at the final block in the design. The INA is designed with the gain of 70dB at 6 KHz with the CMRR of 98dB. The SNR of proposed design is 100dB.

VII. References

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