DESIGN OF A HIGH GAIN, TEMPERATURE COMPENSATED INSTRUMENTATION AMPLIFIER

DISSERTATION-II

Submitted in partial fulfillment of the
Requirement for the award of the
Degree of

MASTER OF TECHNOLOGY

By

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CERTIFICATE

This is to certify that **Prabhjot Kur** bearing Registration no.11612333 have completed objective formulation of his Base Paper implementation of the thesis titled, **“Design of a High Gain, Temperature Compensated Instrumentation Amplifier”** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of thesis has ever been submitted for any other degree at any university.

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ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude and appreciation to my guide **Raghav Gupta,** for his whole-hearted and invaluable guidance, inspiring discussions, encouragement, and support throughout my work. I found him always sincere in helping me even during his busiest hours of the day. His ardor and earnestness for studies are respected and will never be forgotten. Without his sustained and sincere effort, this report would not have taken this shape.

We are also indebted to all authors of the research papers and books referred to, which have helped us in carrying out the research work.

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DECLARATION

I, **Prabhjot Kaur**, student of M. Tech VLSI under School of Electronics and Electrical Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this **Dissertation-II** report is based on my own intensive research and is genuine.

This report does not, to the best of our knowledge, contain part of my work which has been submitted for the award of my degree either of this University or any other University without proper citation.

Signature :

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ABSTRACT

Biopotential signals are important to physicians for diagnosing medical conditions in patients. Traditionally, biopotentials are acquired using contact electrodes together with instrumentation amplifiers (INAs). The biopotentials are generally weak and in the presence of stronger common mode signals. The INA thus needs to have very good Common Mode Rejection Ratio (CMRR) to amplify the weak biopotential while rejecting the stronger common mode interferers. Op-amp based INAs with a resistor-capacitor feedback are suitable for acquiring biopotentials with low power and low noise performance. However, CMRR of such INA topologies is typically very poor. In this work the three stage op-amp is designed in order to get the high gain and that is used to design the high gain instrumentational amplifier.

LIST OF ABBREVIATIONS

CBIA	**Current Balancing Instrumentation Amplifier**
ECG	**Electrocardiography**
EEG	**Electroencephalography**
EMG	**Electromyography**
INA/IN	**Instrumentation Amplifier**
Op-amp	**Operational Amplifier**
SNR	**Signal to Noise Ratio**
CMRR	**Common Mode Rejection Ratio**
PSRR	**Power Supply Rejection Ratio**

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CHAPTER 1

INTRODUCTION

The endeavors to amplify_bio-signal initiated along expansion of electrocardiography. In Researcher successively calculated electrocardiography of their puppy by means of two basins of salt,that contains both of frontal paws along with rear paws was submerged. Following couple of months, Waller effectively record the primary individual electrocardiography utilizing the capillary electrometer. Despite the fact that, Waller had not imagined that the electrocardiography could be utilized as a part of medicinal services extensible, at the moment of his creation. The electrocardiography was not having a use in practical as far as a Dutch physiologist, authored a best approach for utilizing the string galvanometer.

By the 1930s, the electrocardiogram gadget was conveyed to the patient's room with end goal of the checking. Along with development of electronic enhancement, they found most of highlights of electrocardiography were uncovered with different electrode placement.

Biopotential signal checking and recording is an important part of medicinal determination and current clinical practice requires these signs to be routinely recorded. It is normally the training that patients are associated with unwieldy chronicle gadgets for the reason for getting signals from the body to help in analysis. This influences their versatility and causes general uneasiness for them. Procurement time diminishes because of this and keeps the nonstop observing of the patients which influences the general determination of illnesses.

Therefore, there has been the developing interest for low-commotion and ultra-low power, small scale wandering biopotential obtaining gadgets. This has required broad research in the plan of such interfaces and the inevitable target is to be ready to outline a biopotential little chronicle framework that is agreeable, with long term control self-governance, has high flag quality and can be arranged to make it helpful for some biomedical applications.

Numerous Instrumentation speakers have been proposed for motivation behind bio-potential signal focusing on power which is low, low noise and huge CMRR determinations. Instrumentation amplifiers (IA) are generally utilized as a part of various estimation applications where it is important to stifle any undesirable common mode signals. Also, to record of the ECG signals, the IA ought to be smaller, lightweight, and devour as little battery control as could be allowed.

1.1 Operational Amplifiers and Instrumentation Amplifiers

These are most common circuits used in analog electronic circuit design. Its uses are very wide and op amps are found in sorts of applications from power management systems to RF circuits and data converters. These properties are desirable in all applications where op amps are used. An amplifier is somewhat of a loose term implying any system or block that produces an output quantity that is a scaled version of its input. The input could be a single ended signal or the difference of two signals. More commonly, the output of an amplifier is a scaled current or voltage. Current and voltage amplifiers can be built using op amps in negative feedback configurations or using entirely different circuit topologies. **Figure 1.1** shows the block diagrams of amplifiers and operational amplifiers.

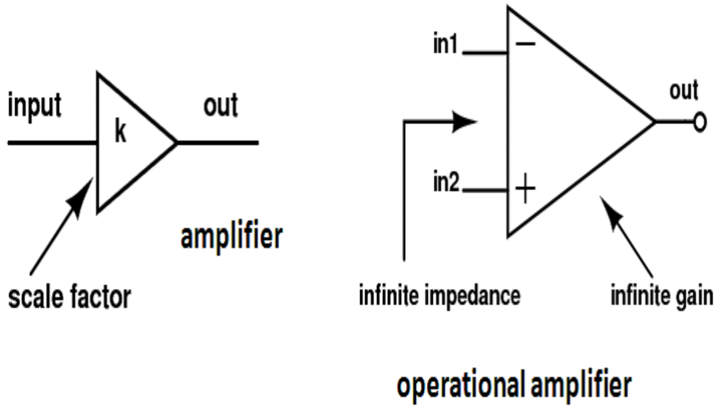

Figure 1.1 Block Diagram of an Amplifier and Operational Amplifier

Table 1.1 Table showing some characteristics of INA's and Op-amps

Properties	Op-amp	INA
Gain	Very Large	Finite
Gain Accuracy	High	Very High
CMRR	High	Very High
Noise	Low	Very Low

Instrumentation Amplifiers (INAs) are exceptional amplifiers outlined where long haul exactness and stability of the amplifier is wanted. These are differential amplifiers in which they have two sources of input and difference of which is calculated to produce the desired output. Most instrumentation amplifiers have no less than one op-amp and some negative feedback system to obtain the desired fixed gain. Nonetheless, it ought to be noticed that there are a couple of open INA topologies too. INAs regularly have exceptionally good common mode rejection ratio. **Table 1.1** demonstrates the general properties of op-amps versus instrumentation amplifiers.

Instrumentation Amplifier is utilized as a part of a large group of sensor applications, for example, temperature and weight detecting. INAs are likewise utilized as a part of biomedical fields. A run of the mill case of such utilize is in the front end of biopotential securing frameworks. **Figure 1.2** indicates four noteworthy application zones of instrumentation amplifiers.

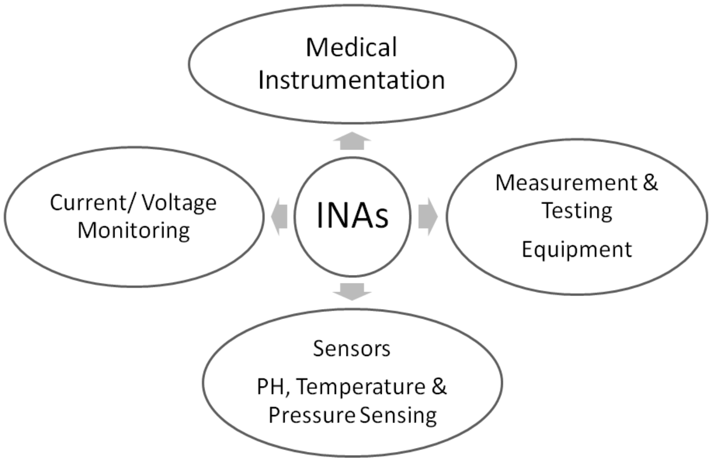

Figure 1.2 Applications of Instrumentation Amplifiers

For this exploration, we for the most part concentrate on utilizing the instrumentation amplifiers for getting the biopotential signals. Such sorts of instrumentation speakers are otherwise called the biopotential signal amplifiers.

1.1.1 Classes of Instrumentation Amplifier

There are numerous approaches to implement instrumentation amplifiers to accomplish long haul stability and efficiency. In general terms, we can classify most topologies under the following 2 types:

- Op-amp based INAs
- Current Balancing INAs

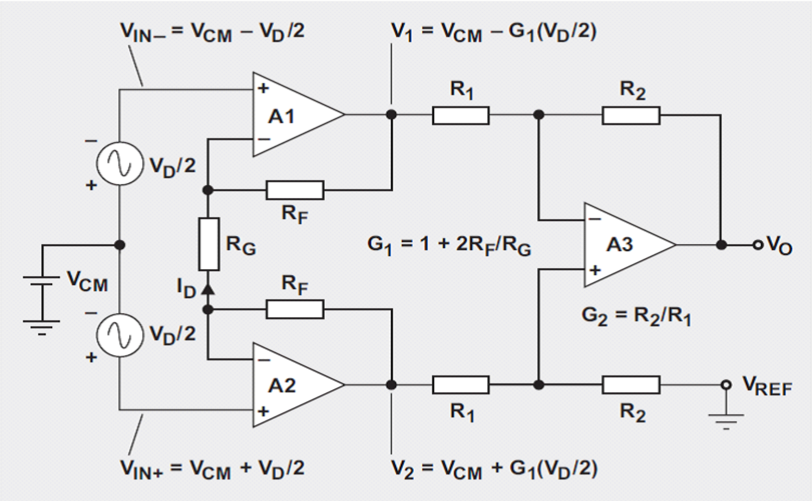

Figure 1.3: Three Op-amp Instrumentation Amplifier

- **<u>Op amp Based INA</u>**

Op-amp based INAs, as the name indicates, utilizes op-amps and the feedback networks for the amplification and frequency shaping if required. The most widely recognized INA topology of this kind is the 3-opamp instrumentation amplifier. This is shown in Fig 3.

The 3 op-amp INA has two stages. The overall gain of the INA is split between the two stages. In Figure 3, the two gain stages amplify the differential input signal by G1 and G2 respectively.

$$G_1 = \frac{v_1}{v_d} = 1 + \frac{2R_F}{R_G} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

$$G_2 = \frac{v_o}{v_1} = \frac{R_2}{R_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

$$G_{total} = G_1 G_2 = \frac{R_2}{R_1}\left(1 + \frac{2R_f}{R_G}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.3)$$

Ideally, this scenario means that the INA has very good rejection of common mode signals. However, the CMRR of the topology ultimately relies upon the proper matching of the passive components, resistors in this case. Asuming 40dB differential gain, the resistors must be coordinated to inside 0.1% of each other to accomplish 100dB of CMRR (Common Mode Rejection Ratio). Let ΔR = Rf – RG and Ac = common mode gain. At that point

$$A_c \approx \frac{\Delta R}{R_f + R_G} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.4)$$

Laser trimming is required to get tolerable CMRR utilizing this topology. In addition, the utilization of 3 op-amps in this topology makes it a high power consuming topology and unsatisfactory for low power application, for example, portable biopotential signal acquisition systems.

- **Current Balancing Instrumentation Amplifiers**

INAs of this topology can be explained by the simplified diagram in Figure 4. The input stage is a transconductance stage and the output is a trans-impedance stage. The input voltage appears across the input resistance and produces a current through it. By some means, (examples of which will be discussed in the following section), this current is mirrored into the output stage and flows through the output resistor and in the process generating the output voltage signal. Thus under ideal conditions, the gain of this INA is defined by the ratio of output to input resistors and the CMRR is independent of the matching between these resistors.

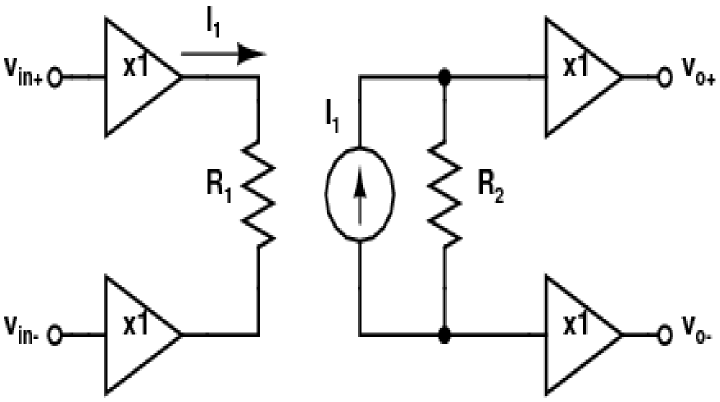

Figure1.4 Concept of Current Balancing INA

The CBIA (Current Balancing Instrumentation Amplifier) idea appears to be extremely simple however the issue is the means by which to copy the current from the input to the output stage. The ideal case assumes that the buffers have no output resistance and that the current source is ideal. A more precise representation of the idea is shown in **Figure1.4**.

$$Av_I = \text{Gain (ideal)} = \frac{R_2}{R_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.5)$$

.

In this case the output resistances of the buffers are accounted for as well as the limited output of the current source

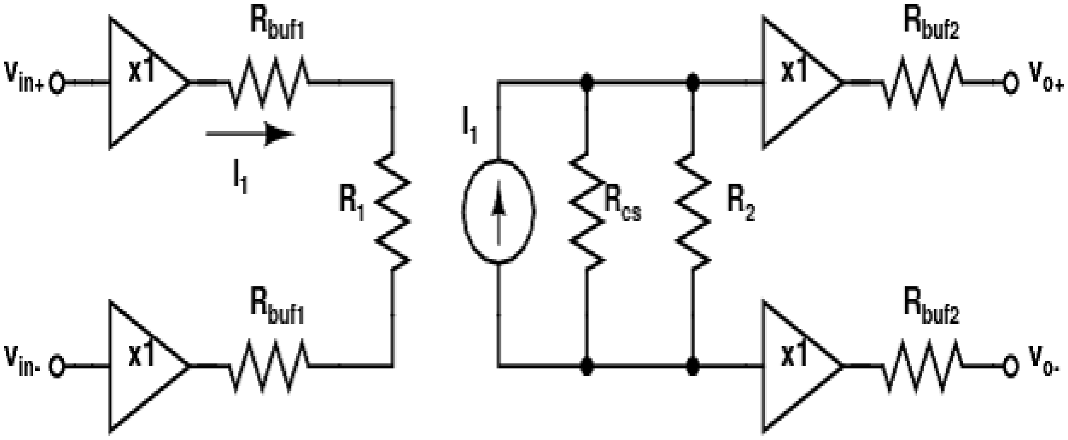

Figure1.5 More Accurate Representation of Current Balancing INA

The gain is defined as shown in equation 1.6.

$$Av_a = \text{Gain (actual)} = \Delta.\frac{R_2}{R_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1.6)$$

$$\Delta = \frac{R_{cs}R_1}{(R_1 + 2R_{buf})(R_2 + R_{cs})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.7)$$

Design & simulation of some of the CBIA topologies shows that the gain accuracy is normally not great because exact mirrors of the input stage current are difficult to reflect in trans-impedance output stage. In equation 1.7, Δ is some fraction less than 1. Δ approaches 1 under ideal conditions when Rbuf is zero and Rcs is infinite. The design procedure of CBIA is also complex than that of the opamp based INA topologies.

1.1.2 Features of Instrumentation Amplifier

This is typically for the sensors to have little measure of enhancement. It is the widely recognized method for signal conditioning, to change over voltage or current into a more elevated amount within an regulated range, for example, 0 - 5 volts. For test purposes and for here and now needs this should normally be possible through an operation amp (instrumentation amp). Modern sensors would be frequently provided with the instrumentation enhancers incorporated with sensor. They can likewise be bought as isolated modules and added to a current framework.

Instrumentation enhancers are operation amps which are mostly DC coupled, designed for differential high impedance,infinte CMRR and hold a single ended output. They regularly incorporate counterbalance trimming and single resistor pick up change.

- **DC coupled**
- **Differential Input**
- **CMRR**
- **High Impedance input**

1.2 Biopotential Amplifier

Bio-signals are being noted as potentials and voltages, created muscles. The estimations include low range voltages, commonly running in range of 1 µV - 100 mV, along large impedances. To make the signals compatible with devices (displays, A/D convertors or recorders), they should be amplified. Amplifiers sufficient to capture these types of signals must fulfill the definite requirements. Amplifiers highlighting these conditions are usually known as biopotential amplifiers.

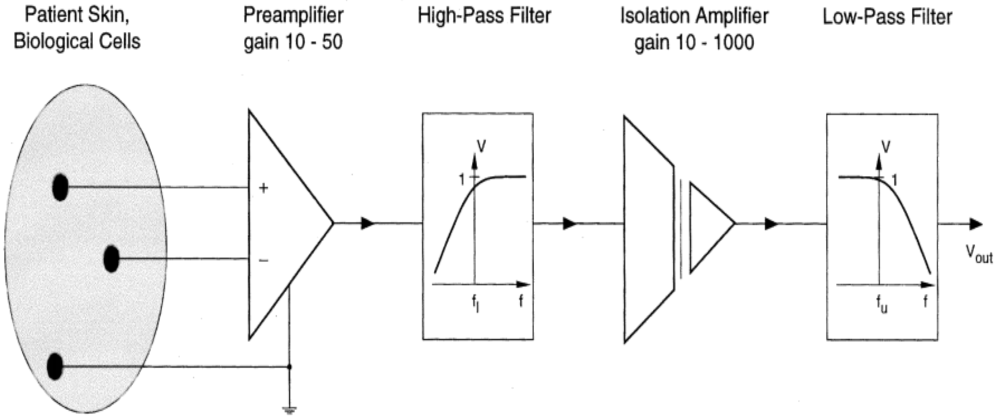

Figure1.6 Design displaying stages of biopotential amplifier

Pre-amplifier stage can be associated to the patient's by using the electrodes. In the pre-amplifier stage, three terminals are associated with the patient. In the wake of expelling dc and low-frequency obstructions, the flag is associated with a yield via a LPF isolation stage which gives electrical security to the patient, anticipates ground circles, and lessens the impact of impedance signals.

1.3 Basic Amplifier pre-requisites:

Following are the fundamental needs that a biopotential amplifier must fulfill:

2 The physiological technique to watch ought not to be affected at all by the intensifier.

3 Calculated signal ought not to damage.

4 An amplifier ought to give the most ideal detachment of the signal and the obstructions.

5 The enhancer brings to the table assurance of the patient from any risk of electrical stun.

6 The intensifier itself must be shielded against harms that may come about because of high info voltages.

1.4 Signal Constraints

The main components of amplifier's input signal are:

- The coveted biopotential signal
- Undesirable biopotential signals
- An electrical cable impedance signal of range 60 Hz (in few nations its is 50 Hz) and its sounds
- Interference signals produced terminal interface
- Unwanted signals

1.5 Design Constraints

The pattern with the advancement in cathodes and amplifiers has been decreasing its range for better portability, and making those implantable on skin for delayed account of the signals. Preamplifiers, head-organize speakers remain the same with the exception of that they ought to have distinctive shape factors.

Signal Interference

A large fraction of signal interferences is being rejected while properly designing the amplifier. The most important function of a differential amplifier is to discard the line frequency impedance that is electro statically attached to the subject.

The preferred biopotential appear like a voltage in between 2 i/p terminals of a differential amplifier so known as the *differential signal*. A line frequency obstruction signal indicates just little changes in the amplitude and the phase between the two calculating cathodes, causing roughly a similar potential at the two data inputs, and thus seems just between the inputs and the ground and is known as *common mode signal*. Proper elimination of the common mode signal standout among most necessary aspect of a favorable biopotential amplifier.

1.5.2 Gain

The amplifier must offer the gain in the range of 100 – 50,000 so as to provide excellent signal quality along with satisfactory voltage level. Along with this the best signal to noise ratio must be taken into consideration. The existence of abnormal state obstruction signals not just break down the nature of the physiological signs, yet in addition confines the composition of the bio-potential amplifier.

1.5.3 SNR

Moreover, there is built-in amplifier disturbance. It comprises of two frequency reliant segments, the inside voltage disturbance. Here in case of amplifier, the overall input noise with parameter bandwidth (B) is computed as the total of its three parts:

$$E_{rms}^2 = \int_{f_1}^{f_2} e_n^2 df + R_s^2 \int_{f_1}^{f_2} i_n^2 df + 4kTR_s B$$

A high SNR ratio, in this manner requires the utilization of low noise amplifier within the limited range of bandwidth. Modern technology offers differential enhancers along with the voltage disturbance of under 10 nV/and the current disturbance under 1 pA/. The two specifications are frequency relying and decline roughly along with the square root of frequency. The correct relationship relies upon innovation of the amplifier input stage. Field impact transistor (FET) pre-amplifiers display around five times the voltage commotion thickness contrasted with BJT's however a present noise thickness which is around hundred times littler.

1.5.4 Bandwidth Limit

Keeping in mind the end goal to fulfill ideal signal quality, the bio-potential intensifier must be changed in accordance with the specific application. In view of the signal parameters, the two bandwidth and the gain factors are picked. Figure 2 exhibits an outline of the most routinely measured bio-potential and demonstrates the typical reaches for magnitude and bandwidth.

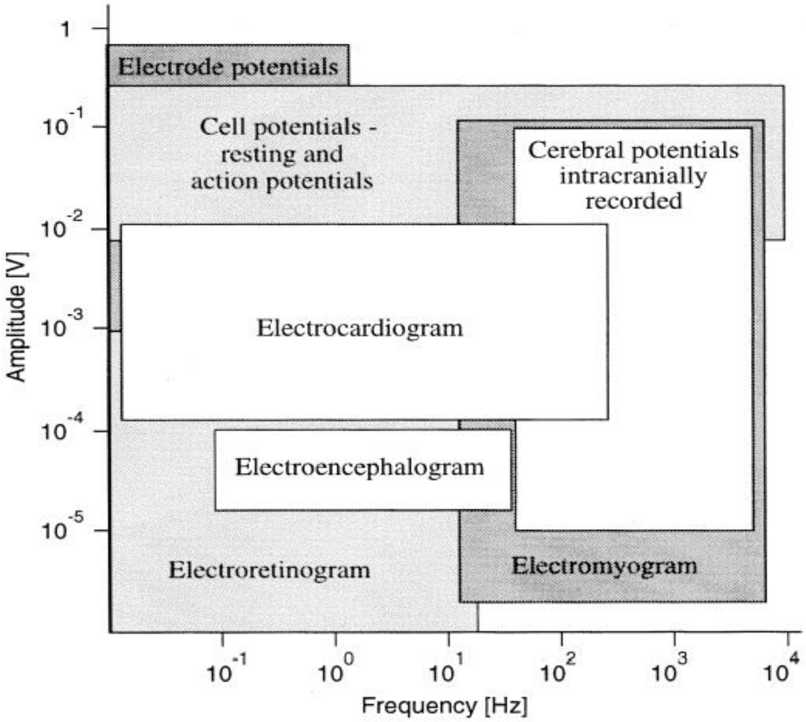

Figure 1.7 Range for magnitude and spectral

The various Biopotential totally take the territory of 10 – 6 Volts to just about 1 V and from dc to 10 kHz.

1.5.5 Isolation

An isolation phase provides galvanic decoupling of a patient from the calculating device and gives well being to quiet from electrical perils. This phase likewise keeps galvanic streams from disintegrating the SNR proportion particularly by avoiding ground circles. Different standards are utilized to understand the isolation stage. In simple analog enhancers we for the most part utilize either transformer, capacitive or optical couplers for transmitting the flag. The attributes of a amplifier are:-

1 High safe isolation voltage
2 Low isolation impedance
3 Low isolation mode rejection (IMR)
4 Low leakage current

1.6 Applications

Bio-amplifier are used for gathering and increasing the signal integrity of the electrical activity. These are commonly used in following applications:-

Electromyography

Electromyography (EMG) instrumentation is used to record the electric action delivered by the skeletal muscles. It files a few sorts of muscle signals from basic unwinding by utilizing setting terminals regarding the matter's brow, to complex intramuscular criticism amid stroke recovery.

Electrocardiography

ECG instrumentation is used to capturethe electrical movement of our heart, over the surface of our thorax skin. The signs are distinguished with the assistance of an anodes connected to the surface of our skin and are filed by an outer gadget. The magnitude of the ECG lies between the range of 0.3 to 2 mV.

Electroencephalography

EEG instrumentation is particularly like the EMG instrumentation regarding situation of the various surface cathodes on the patient's skin, particularly, on the scalp of a patient. EMG achieves signals from the muscles underneath skin whereas EEG secures signals regarding the matter's scalp, produced by their cerebrum cells.

Superior differential enhancers are to be utilized for amplification. Signs of intrigue lie in the scope of 0.5– 100 mV (bandwidth of 1– 50 Hz range).

CHAPTER 2

LITERATURE REVIEW

2.1 Design of a High Gain, Temperature Compensated Biomedical Instrumentation Amplifier for EEG Applications

Aditi Jain, Kavindra Kandpal 2017

IA is being proposed for EEG signal processing which also offers low power. The three phase op-amp IA has been drafted by making use of the sub-threshold 3phase op-amps with PMOS acting as input. Passive resistors of IA have been replaced by the NMOS transistors which are being operated in the triode region. This cancels the disputes of inequality, temperature relying and a wide area utilisation, also having plus point to show the characteristics of traditional IA. Biasing of the op-amp was done using a band gap reference circuitry with temperature coefficient of 420 ppm/oC. The IA is being simulated in Cadence Virtuoso 180nm CMOS technology with a supply of IV. It acquires a Gain of 96.4dB.

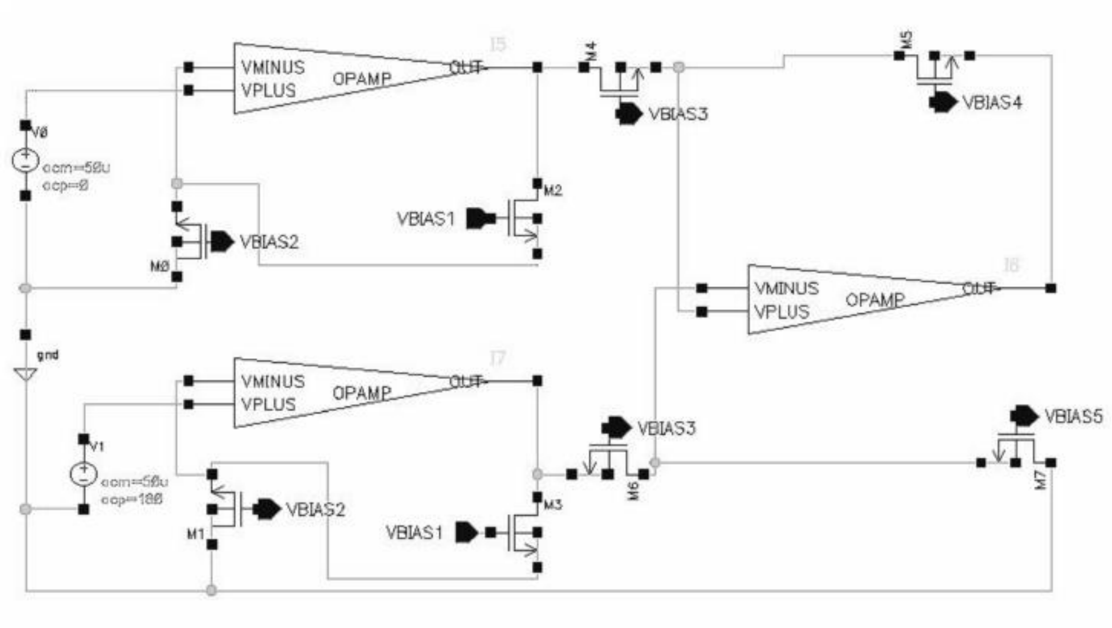

Figure 2.1 Three stage IA using three stage op-amp.

2.2 Design of CMOS Instrumentation Amplifier with Improved Gain & CMRR for Low Power Sensor Applications

Buddhi Prakash Sharma and Rajesh Mehra 2016

This paper reveals about a high performance instrumentation amplifier based on operational amplifier (op-amp) for low power applications. The instrumentation amplifier (IA) has been designed for low power application while maintaining the factors like high gain, high CMRR, low noise as well as other design constraints. The Instrumentation amplifier is designed using two the identical two stage op-amps at the input (gain) stage and one difference amplifier at output stage. By using the operational amplifier at the gain stage in saturation region and the difference amplifier at the output stage in sub threshold region to achieve high gain and CMRR. Aspect ratio (W/L) plays crucial role in achieving the design constraints. The whole instrumentation amplifier schematic is designed and simulated at 180nm CMOS technology using Cadence Spectre tool. The instrumentation amplifier achieves an overall gain and CMRR of 79.16 dB and 98 dB .

2.3 DC Suppressed High Gain Active CMOS Instrumentation Amplifier for Biomedical Application

Manish Goswami and Smrirti Khanna 2011

In this paper an IA (used for biomedical applications) is presented which is designed using three phase op-amp. This op-amp is active resistance. In this high gain is obtained by selecting W/L ratio of operational amplifiers and by adequate designing of passive resistances by using the active MOS transistors. Offset cancellation circuit is used at the output of the IA for the purpose of DC suppression. The offset cancellation circuitry is designed using suitable arrangement of switches (transmission gates) and capacitance.. The IA is simulated in Cadence Spectre 500nm CMOS technology. It attains Gain of 45dB, CMRR achieved is 75dB.

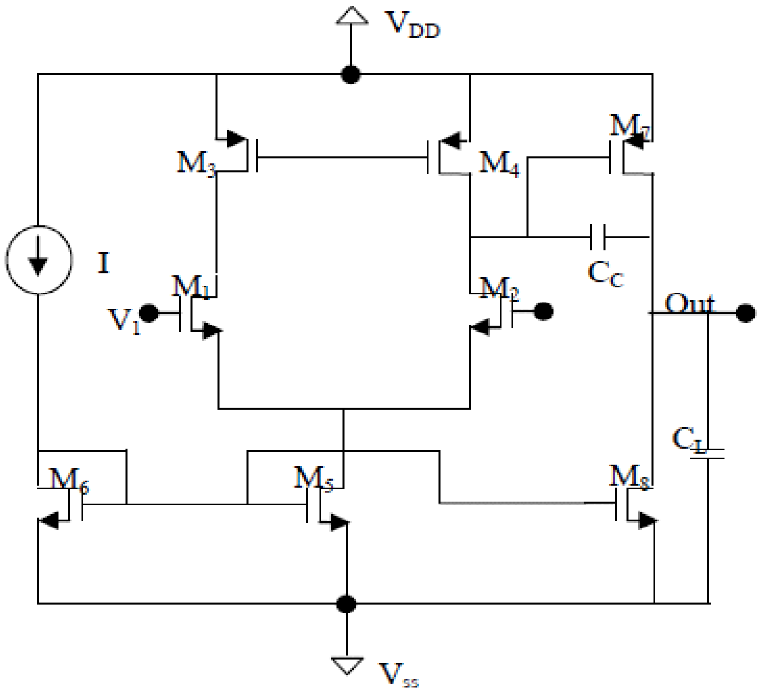

Figure 2.2 2 Stage Op-Amp

2.4 Ultra Low Power ECG Acquisition Front-end with Enhanced Common Mode Rejection

Prathamesh Khatavkar, Aravind Nagulu, Sankaran Aniruddhan 2016

An ultra-low power low noise analog front-end for ECG signal acquisition is designed. In comparison with the last done work, in this work the front-end design provides an increase in the CMRR without any co-operation in the quality of the signal. For further improvements efficiency of the IA , it is designed using a Chopper stabilization and current reuse method. Along with this common mode f/b loop is designed to decrease interferences which boosts the CMRR upto 139 dB at the range of power 50 Hz. This design is at 2 kHz is implemented in a TSMC 0.18 μm CMOS technology. It was able to achieve an input referred noise voltage of range 90 nV/pHz with exhausting a current of 350 nA /channel with supply of 1.5 V.

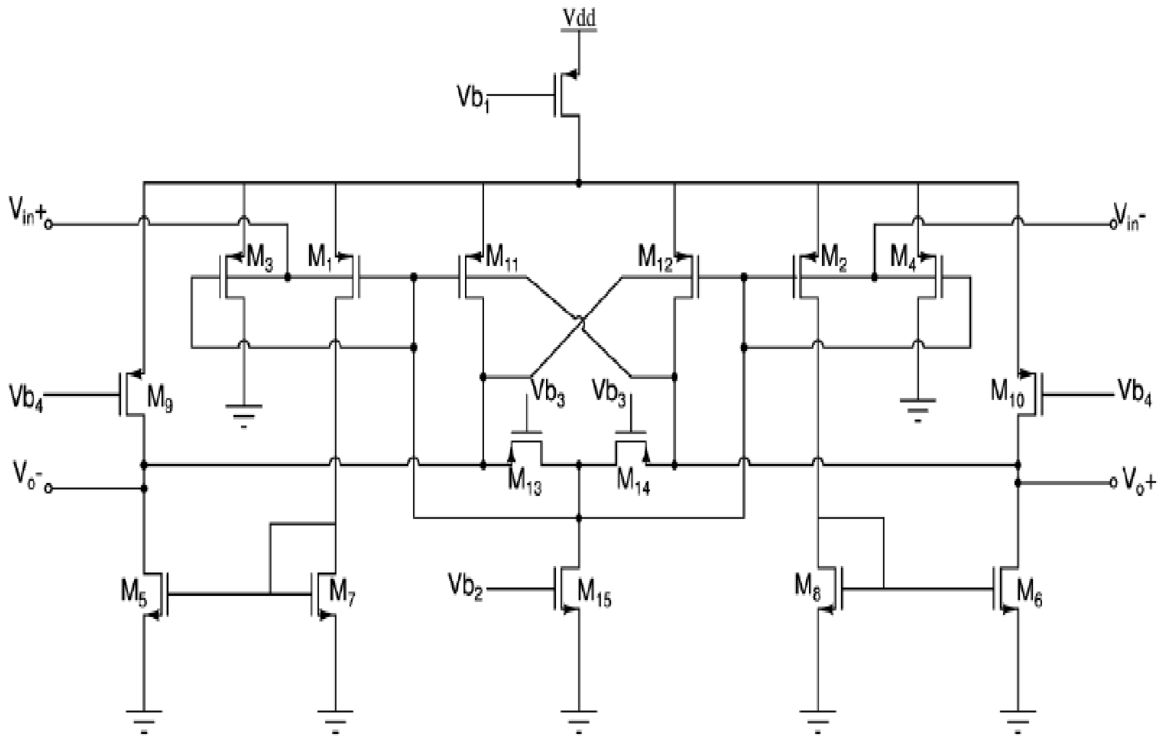

Figure 2.3 Gm Cell

2.6 A New CFOA-Based Low Frequency Low pass Filter for Biomedical Applications

Muhammad TaherAbuelma'atti and Sagar Kumar Dhar

A new floating active inductance (FAI) realization was proposed here. The FAI had been used to form a low frequency low pass filter with cutoff frequencies in the low frequency region. The Simulation results using the current-feedback operational-amplifier (CFOA) AD844 ensured the correct functionality of the design. So this low frequency LPF would be quite useful for biomedical applications that require to work at frequencies approximately near 100 Hz.

2.7 Design of a Low Noise Low Power Preamplifier used for Portable Biomedical Signal Acquisition

Yali Su and Xuan Liu

In this paper a preamplifier (low noise) is being designed for signal acquisition for biomedical applications. A “T-type feedback” op-amp topology arrangement is used based on the conventional “AC coupling-capacitor feedback”. The resultant amp is designed in SMIC 0.18um standard CMOS process, forms signals ranging between 0.2/25Hz - 10 kHz with input-referred noise of 0.96 µVrms and the power dissipation of 18.54µW while covering almost 0.065 mm2 area of chip. The preamplifier after simulating attains the best gain, bandwidth along with small area consumption and minimum input referred noise.

2.8 Design of Low Power CMOS Sub threshold Current Mode Instrumentation Amplifier Based on CCII

Mohammed A. Eldeeb ,Yehya H. Ghallab , Yehea Ismail and Hassan Elghitan

In this paper, a low power current mode IA dedicated to biomedical applications based on current conveyor circuitry is designed. All MOSFETs works in the sub threshold region producing, high energy efficiency using a 0.4V supply (single ended). It’s designed using conventional CMOS technology which can be easily integrated into VLSI circuits. For this proposed design the post layout analysis was done using TSMC 90 nm technology.

Flicker noise is reduced by using the Chopping technique upto the value of 3.59 µVRMS for bandwidth ranging between 0.2- 150 Hz. A high CMRR of 107 dB is obtained while utilizing 5.5 µW of power with maximum gain of 41 dB. The chip area for this design is of the dimension 0.023 mm2.

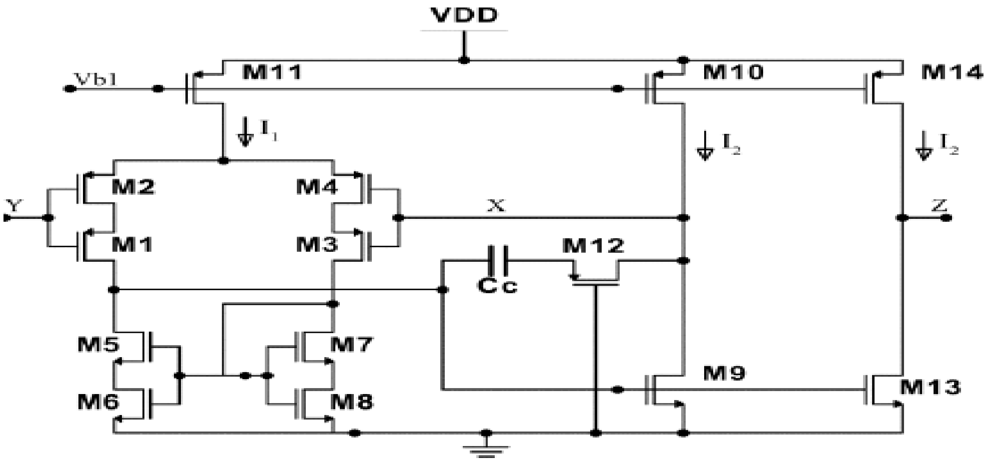

Figure 2.4 Current mode IA amplifier.

CHAPTER 3

SCOPE OF THE STUDY

3.1 Objectives

EEG indicates to the copying of the electrical signals of mind to analyze the disarranges, for example, trance state. But, catching of these signs is exceptionally troublesome and inconvenient because of the fact that these signals are extremely black out and can be effortlessly drowned. The signals are in the range of 0.1 to 100 uV. So in order to capture these signals they are needed to be amplified several times. If we connect the patient to bulky system for diagnosis it becomes very much uncomfortable. Hence the biomedical electronics is advancing fastly with the improvement in the VLSI techniques facilitating research for large gain, less power consumption and less area requirement.

These days, designing of the less power consumption and the high gain, high speed achievement and area reduction has become a major issue in the VLSI circuits. There is a rising claims of low power dissipation in the biopotential signals storing devices for long battery life achievement and also the better constant monitoring. The amplifier is one of the most power consuming block in the analog frontend design. So, the design move is towards the designing of the amplifier where the transistors operates in the sub-threshold region which is much appropriate for the low power.

The main objective of my thesis is to reduce the power in the circuit and increase the gain, CMRR and the noise of the instrumentation amplifier circuit in order to make it useful for the signal recording in EEG application.

3.2 Problem Formulation

To develop the performance of VLSI circuits in the bio-medical electronics the size of the amplifier used in the biomedical applications is decreasing day by day. Power dissipation, delay, gain, CMRR are the main factors with which we as VLSI design engineers are facing today. In this, proposed a high gain biomedical instrumentation amplifier using the three stage operational amplifier. In this IA the resistor of the basic IA are replaced with the MOSFET’s as to decrease the area consumption of the amplifier chip and also the total power consumption.

In the last few decades there is a large significant development in the scenario of design. Amplifiers are the basic building block of the instrumentation purpose devices in the biomedical applications.

In this we have observed a point in the circuit that the gain, CMRR etc. plays an important role in the working of instrumentational amplifier. Also the common mode rejection ratio of the circuit is 60 db which is quite below the range of the standard value of the of CMRR for biomedical signals (107-110 db). So the improvement will be done in the operational amplifier circuit so as to achieve overall high gain and the high common mode rejection ratio of the instrumentational amplifier.

The first stage of the proposed op-amp operates in the region called sub-threshold and the other two stages operates in the saturation region. If we try to increase the stages of the op-amp circuit then the area overhead, delay and the power consumption factors will also effect the circuit. So modification in the op-amp circuit will be done taking the factors into consideration so as to improve the overall performance of the circuit.

CHAPTER 4

PRESENT WORK (Base Paper Implementation)

An instrumentation amplifier is a type of differential amplifier which is being outfitted with input buffer amplifiers. This all is done to eliminate the input impedance matching and therefore making design especially suitable for the measuring applications. An amplifier with large values values of CMRR is appropriate for biomedical detecting applications and **Figure 4.1** demonstrates the typical I.A .

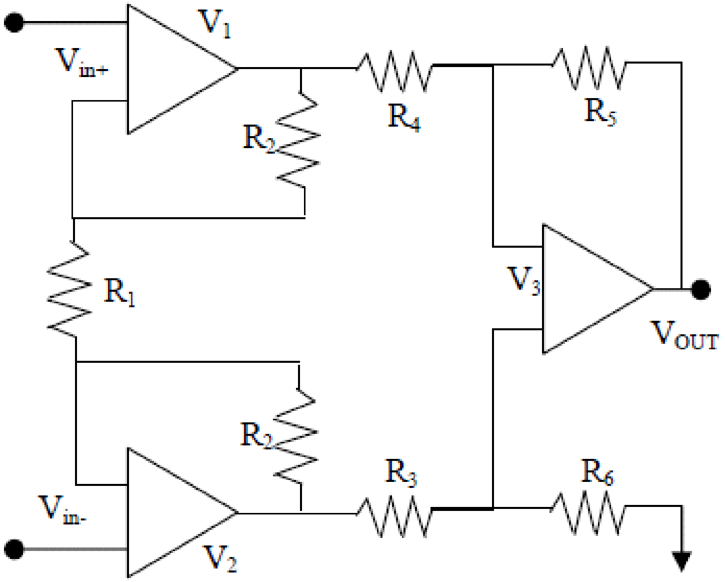

Figure 4.1 Typical IA

In the three op-amp design of the instrumentation amplifier (bio-potential amplifier), op-amp makes the basic building block of the all structure. The advantages of an IA are:

- Large input impedance
- Large CMRR
- Large gain
- Less noise response
- Less power dissipation

4.1 Circuit Design

The described has 3 stages. The first stage operates in the sub-threshold region, where as in second and third stages it operates in the region known as saturation region.

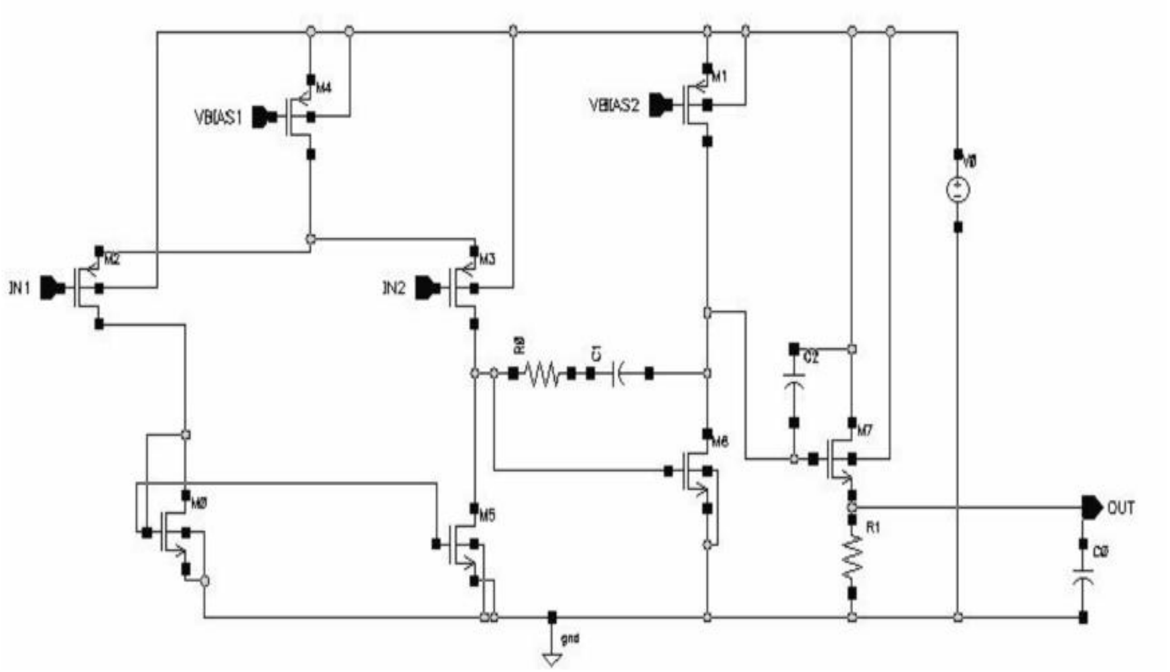

Figure 4.2 Three stage op-amp

The instrumentation amplifier is implemented using the above three stage op-amp circuit as shown in **Figure 4.2**. Typically in Instrumentation amplifier the first stage amplifies the input signal and the common mode signal is passed as it is to input of the second stage. 2nd stage is the unity gain stage used as the differential amplifier.

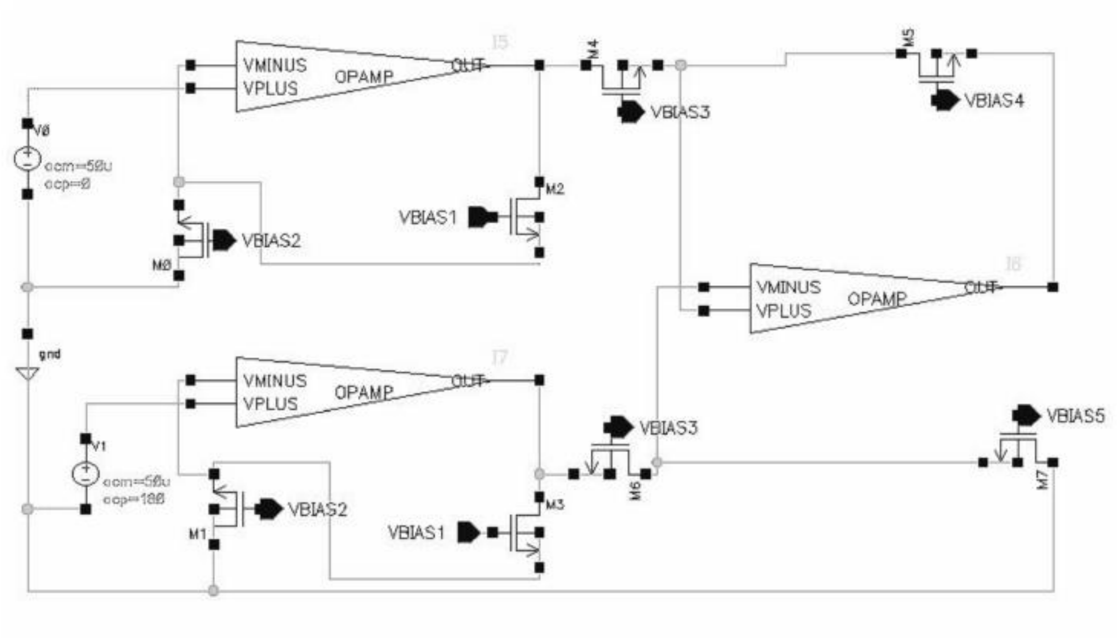

Figure 4.3 Three stage IA using three stage op-amp

4.2 Circuit Analysis

In the three stage op-amp shown in **Figure 4.3** the drain current of n-channel mosfet in the sub-threshold region is given by equation:

$$I_d = \frac{W}{L} I_o e^{Vgs-Vth/mVt}(1 - e^{-Vds/Vt} \approx I_d = \frac{W}{L} I_o e^{Vgs-Vth/mVt} \qquad \text{...............(4.1)}$$

From equation4.1 the transconductance (g_m) and resistance rd(drain to source) are given by

$$g_m = \frac{\partial Id}{\partial Vgs} = \frac{Id}{mVth} \qquad \text{..(4.2)}$$

$$r_d = \left[\frac{\partial Id}{\partial Vds}\right]^{-1} = \frac{mVth}{\gamma dId} \qquad \text{...(4.3)}$$

The total open loop DC gain of the op-amp is specified by the following equation

$$A_v = g_{m3}(r_{o3}||r_{o5}) * g_{m6}(r_{o1}||r_{o6}) \qquad \text{..(4.4)}$$

.

Where g_{mi} is the transconductance and r_{oi} is the drain source resistance.

4.3 Circuit Schematic and Simulation results

The op-amp designed has been displayed in **Figure 4.4.** The i/p stage consists of the differential pair of transistors(PMOS) M2 and M3 and a current mirror load of transistors(NMOS) M0 & M4. Here the utilization of PMOS transistors in the input stage is an good option to reduce the flicker noise. For the proper biasing of the circuit, NMOS transistor (M4) is used which forms a current sink.

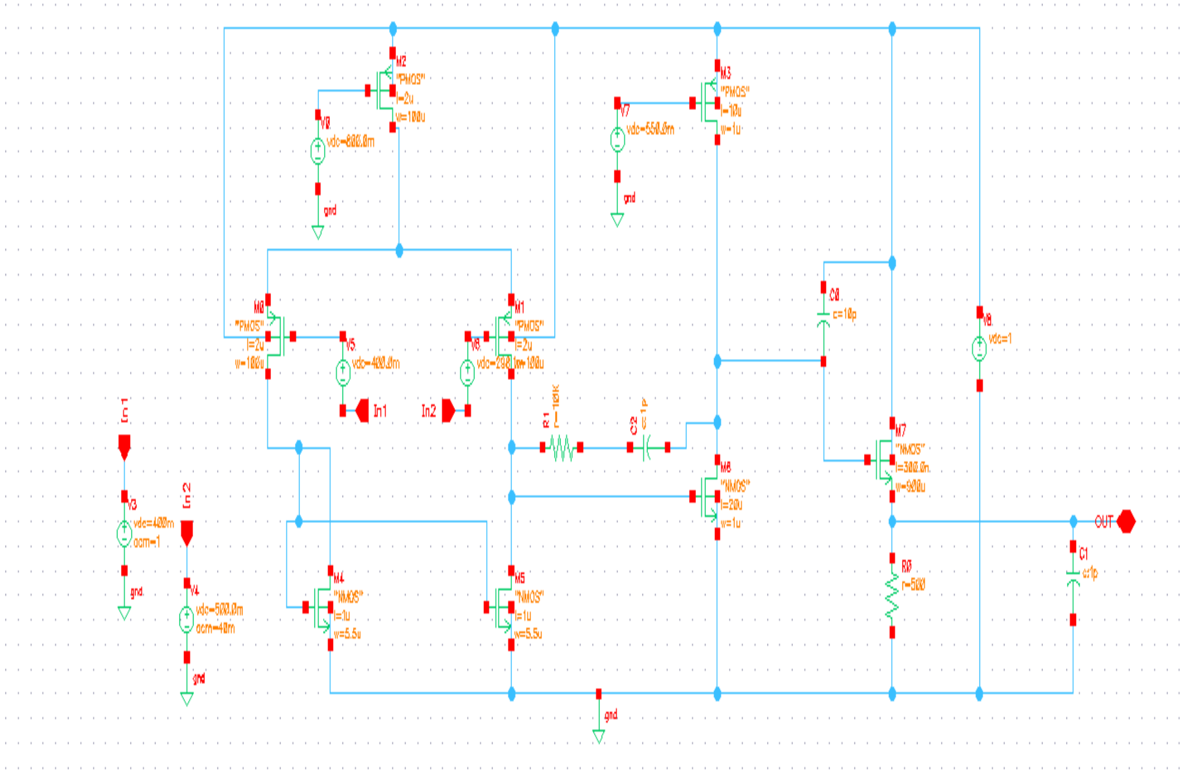

Figure 4.4 Implemented three stage op-amp.

In the above circuit the following values of the aspect ratio of transistors are considered in order to design the op-amp.

Table 4.1 Aspect Ratio of transistors

TRANSISTORS	ASPECT RATIO OF TR.(W/L)
M0	100u/2u
M1	110u/2u
M2	100u/2u
M3	1u/10u

M4	5.5u/1u
M5	5.5u/1u
M6	1u/20u
M7	900u/.0u

The gain to be calculated for this specified circuit of the three stage op-amp is as

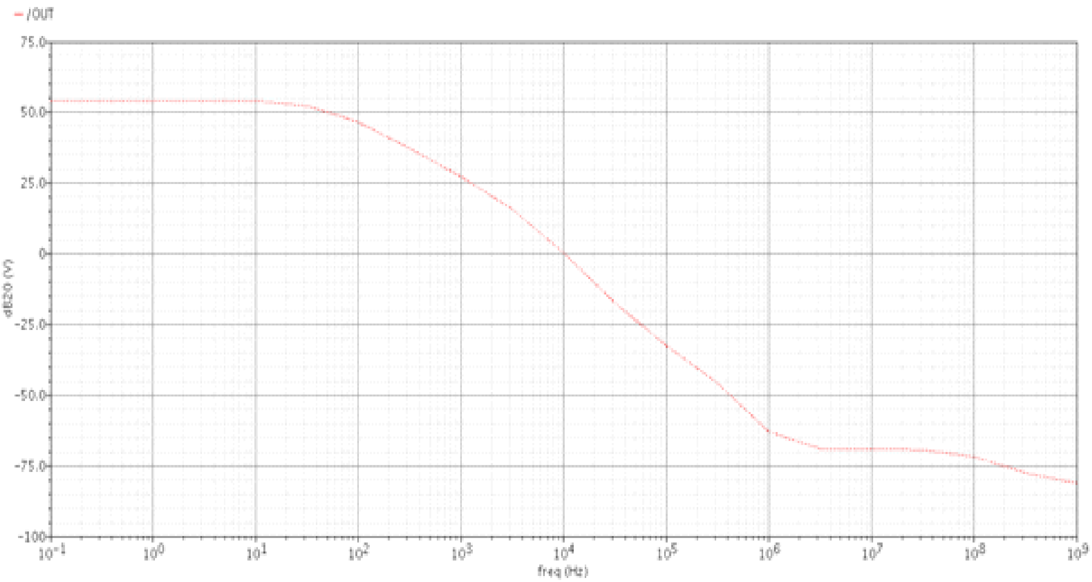

Figure 4.5 Gain of circuit

The gain of the op-amp circuit is coming out to be 53.4 db. In this we use the first stage transistors in the region known as the sub-threshold region. This is because the sub-threshold region is appropriate for the low power applications. In this the gain after the second stage was coming out to be 30.1db which was very less. So to boost the gain third stage was added in which the transistors operate in the saturation region.

Instrumentation amplifier:

The IA is implemented using the above op-amp. In this the gain of 96 db is achievable.

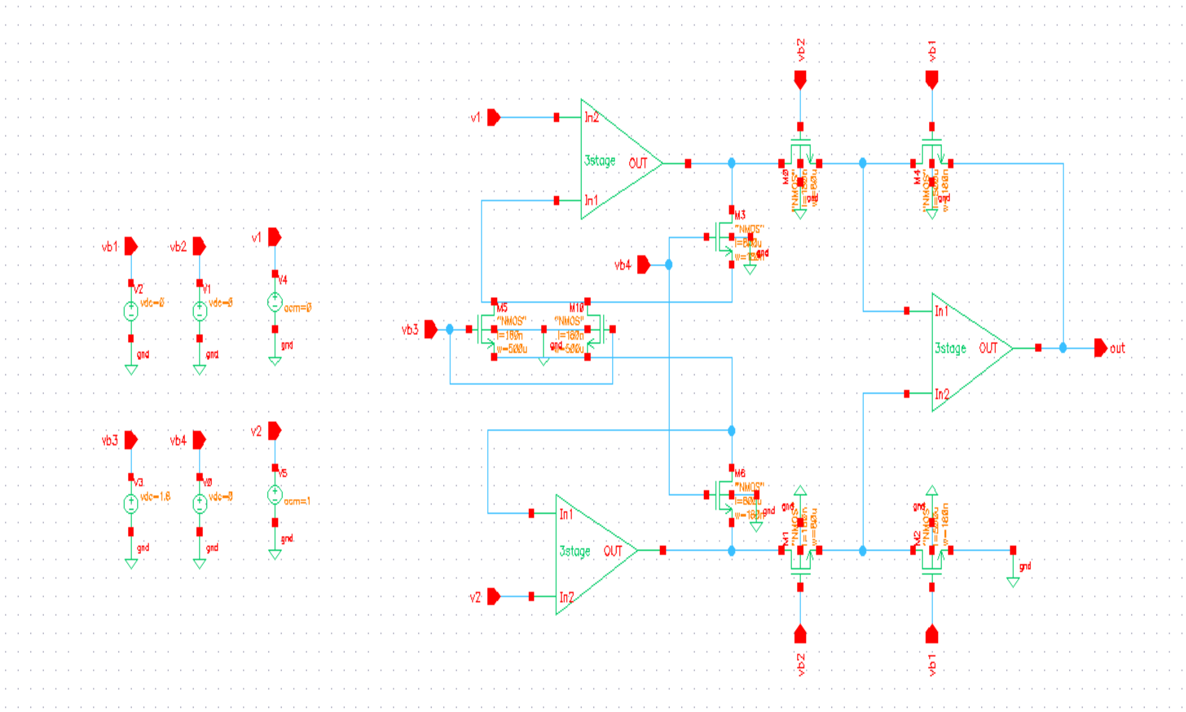

Figure 4.6 Implemented Instrumentation amplifier.

The following are the results of the instrumentation amplifier including the gain, common mode ratio and the PSRR.

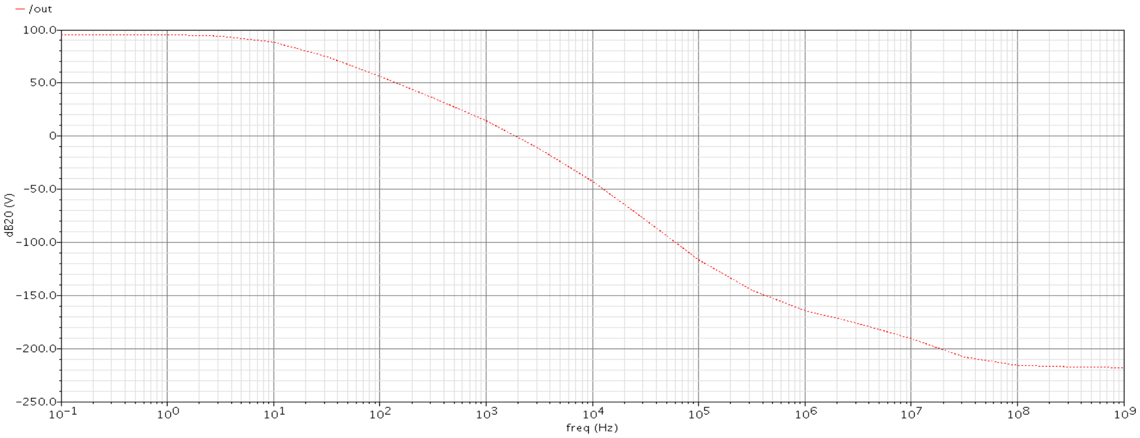

Figure 4.7 Gain of instrumentation amplifier circuit

The gain of the instrumentation amplifier circuit calculated is 96.1 db which is quite good for the instrumentation amplifier as it will help to capture the low power EEG signals well and does not let to false outputs.

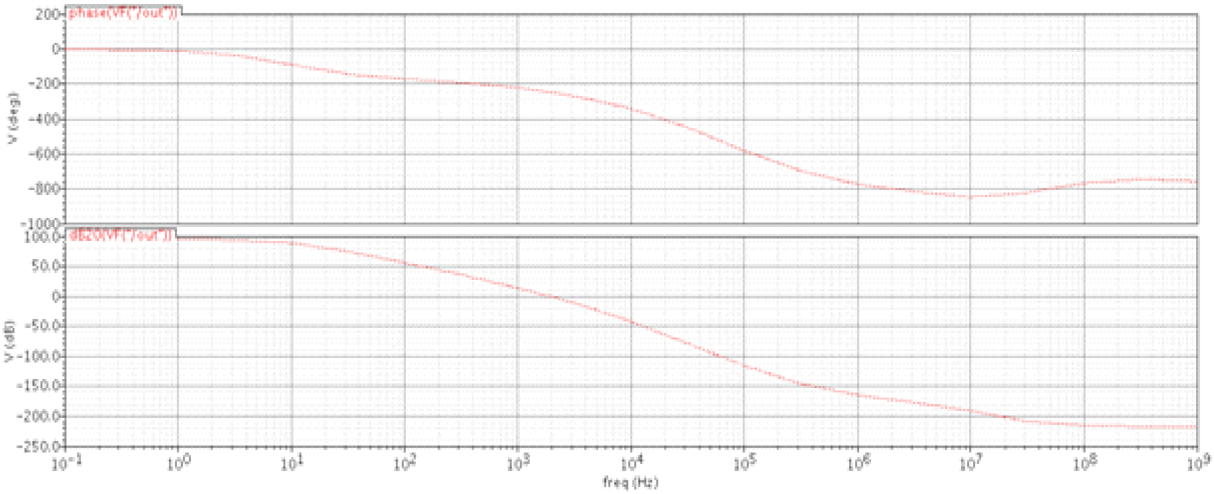

Figure 4.8 Gain and phase plot of instrumentation amplifier circuit

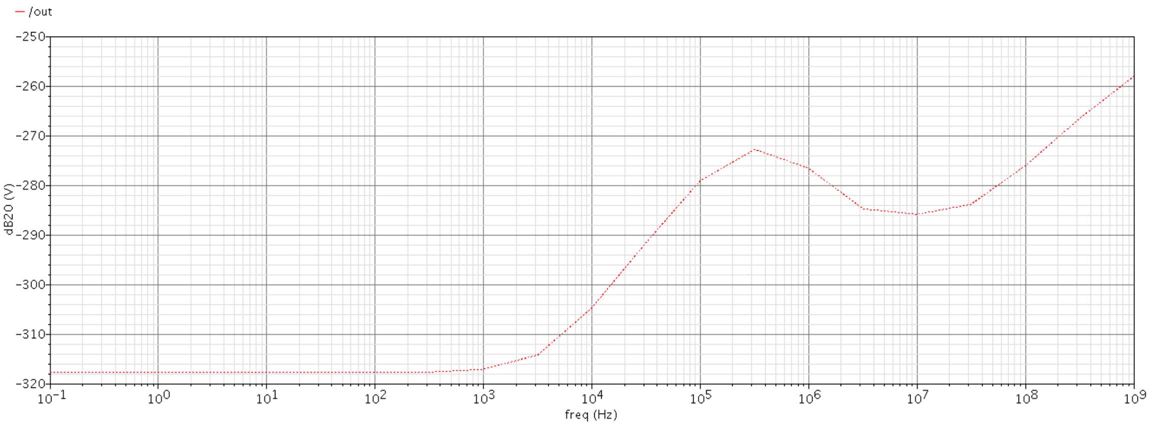

Figure 4.9 PSRR plot of instrumentation amplifier circuit

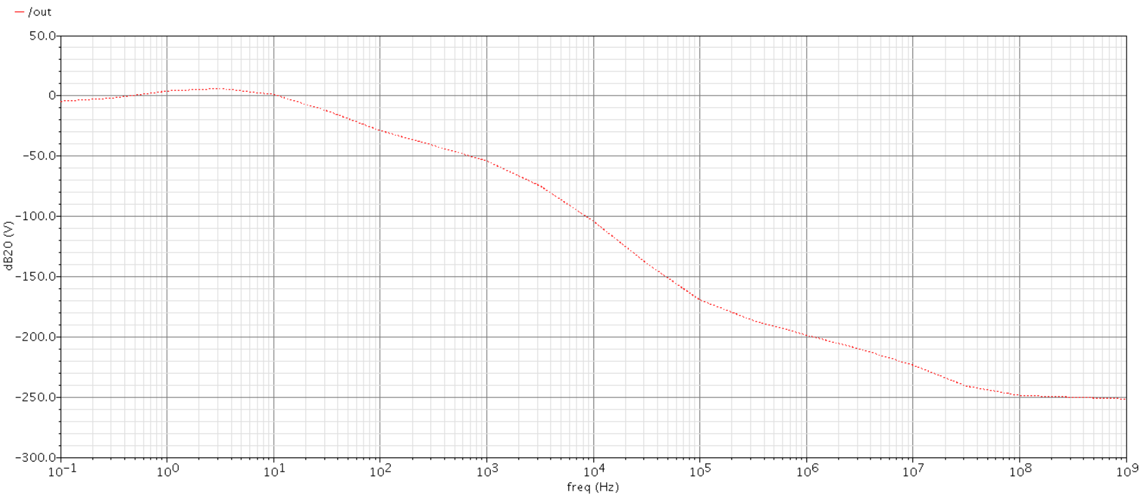

Figure 4.10 Common mode plot of instrumentation amplifier circuit

CHAPTER 5

CONCLUSION

The instrumenation amplifier is designed for the biomedical applications. The designed instrumentation amplifier offer high gain and the low power consumption. The aim was to achieve high gain, less chip area, the percentage of the output to be right and the ability to detect the low signals using the IA that is being achieved.

CHAPTER 6

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