Design of Low Pass Filter Using OTA for ECG Signal Acquisition

PROJECT REPORT

Submitted in the fulfilment of the requirements for

the award of the degree of

Bachelor of Technology
in
Electronics and Communication Engineering

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(ACCREDITED BY **NAAC** WITH **"A$^+$"** GRADE)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
(ACCREDITED BY **NBA**)

VIGNAN'S FOUNDATION FOR SCIENCE, TECHNOLOGY AND RESEARCH
(Deemed to be University)

Vadlamudi, Guntur, Andhra Pradesh, India -522213

May 2024

CERTIFICATE

This is to certify that the project report entitled **"Design Of Low Pass Filter Using OTA For ECG Signal Acquisition "** that is being submitted **by Dudaka Bhuvana Chandra (211LA05002), Aluri Sai Srujan (211LA05023)**, **Gogineni Devi Sai Sunanda (211LA05026)**, and **Pamidiboina Ravi Teja (211LA05043)** in fulfillment for the award of B.Tech degree in Electronics and Communication Engineering to Vignan's Foundation for Science, Technology, and Research is a record of bonafied work carried out by them under the guidance of **Dr. P.Vijaya Lakshmi** of the ECE Department.

24/5/24

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DECLARATION

We hereby declare that the project report entitled "**Design of Low Pass Filter Using OTA For ECG Signal Acquisition**" is being submitted to Vignan's Foundation for Science, Technology and Research (Deemed to be University) in fulfillment for the award of B.Tech degree in Electronics and Communication Engineering. The work was originally designed and executed by us under the guidance of Dr. P. Vijaya Lakshmi at the Department of Electronics and Communication Engineering, Vignan's Foundation for Science Technology and Research (Deemed to be University) and was not a duplication of work done by someone else. We hold the responsibility of the originality of the work incorporated into this project report.

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ABSTRACT

Low-pass filters are essential components in biomedical applications, particularly in electrocardiogram (ECG) signal processing. The ECG signal is a low-frequency signal, typically ranging from 0.05 to 100 Hz, and it is often contaminated with high-frequency noise and interference. Low-pass filters are used to attenuate these unwanted signals and extract the ECG signal of interest. Operational trans-conductance amplifiers (OTAs) are versatile analog building blocks that can be used to implement low-pass filters with high performance and low power consumption. OTAs are particularly well-suited for ECG applications because their transconductance can be easily controlled, making it possible to design filters with precise cutoff frequencies.

There are several different ways to design low-pass filters using OTAs. One common approach is to use a cascade of OTA-C stages. Each OTA-C stage has a single pole, and the number of stages determines the overall order of the filter. A higher-order filter has a sharper cutoff and can attenuate high-frequency noise more effectively. Another common approach is to use a feedback loop around an OTA. This type of filter is called an active-RC filter.

Active-RC filters can be designed to have a variety of frequency responses, including Butterworth, Chebyshev, and Bessel responses. The design of an OTA-based low-pass filter for ECG applications involves several key considerations. The cutoff frequency of the filter must be chosen carefully to ensure that the ECG signal is not attenuated. The filter must also have a sufficiently high dynamic range to accommodate the full range of ECG amplitudes. The power consumption of the filter is also important, as ECG devices are often battery-powered.

Major Design (Final Year Project Work) Experience Information

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Project Title	Design of Low Pass Filter Using OTA for ECG Signal Acquisition
Program Concentration Area	Analog Circuit Design
Constraints	
Economic	No as software is available
Environmental	Friendly
Sustainability	Designed to work for a long period
Manufacturability	Yes as fabrication is a strong constraint in VLSI projects
Ethical	Followed standard professional ethics
Health and Safety	No as it's a simulation work
Social	Applicable for wearable and implantable devices
Political	None
Other	No
Standards	
1. IEEE 1801-2009/2018	IEEE standard for design and verification of Low Power energy Aware Electronic Systems
2. IEEE 11073	For ECG Signal acquisition
Pre-requisite Courses Required for the Major Design Experience	1. Electronic Devices and Circuits 2. Analog Electronics 3. VLSI design

Supervisor

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24/5/24

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

BD	Bulk-Driven
BPF	Band Pass Filter
BSF	Band Stop Filter
CMOS	Complementary Metal Oxide Semi-conductor
CMRR	Common Mode Rejection Ratio
CMFB	Common Mode Feedback
DR	Dynamic Range
DT	Dynamic Threshold
dB	Decibels
DDA	Differential Difference Amplifier
ECG/EKG	Electrocardiogram
EDA	Electronic Design Automation
EEG	Electroencephalogram
EMG	Electromyography
FG	Floating Gate
FPGA	Field Programmable Gate Array
Gm	Transconductance
HPF	High-Pass Filter
LNA	Low Noise Amplifier
LPF	Low-Pass Filter
MOS	Metal Oxide Semi-conductor
OP-AMP	Operational Amplifier
OTA	Operational Transconductance Amplifiers
PPF	Partial Positive Feedback
QFG	Quasi-Floating Gate
THD	Total Harmonic Distortion
VCCS	Voltage Controlled Current Source
VCVS	Voltage Controlled Voltage Source
VLSI	Very Large Scale Integrations

CHAPTER 1

INTRODUCTION

1.1 ANALOG FRONT END:

Nowadays, systems such as portable, battery-operated, and self-powered electronics require extremely low-voltage operation capability and low power consumption. In biomedical systems, such as data acquisition systems for electrocardiographic (ECG) signal processing, low-voltage and low-power analog circuits are required at the front-end of the systems. Analog circuits, such as amplifiers and filters, are usually used to realize the front end. Some examples include the operational amplifier (op-amp), the transconductance amplifier (OTA)[1], and the differential difference amplifier (DDA)[2], which is based on complementary metal-oxide-semiconductor (CMOS) technologies.

In the analog portion, reducing the voltage supply degrades the performance of the performance of the analog circuit, such as the dynamic range (DR), bandwidth, and linearity. To maintain the required DR when the voltage supply is reduced, the input voltage swing should be increased. It is well known that circuits capable of rail-to-rail input voltage swing are the best solution for maintaining the required DR when the circuits are operated with a low voltage supply. The original technique for implementing the rail-to-rail input voltage swing of circuits is the use of differential pairs that are composed of both PMOS and NMOS transistors[3].

However, this technique is complex due to the additional differential pair, current branches, and circuitry used to maintain constant transconductance over the whole input voltage range. Moreover, this technique is not the most suitable for circuits that operate with a low power supply and low power consumption. Therefore, non-conventional techniques, such as bulk-driven (BD), floating-gate (FG)[4], quasi-floating gate (QFG)[5], or dynamic threshold voltage (DT)[6][7][8], which are suitable for circuits operating with low supply voltages, have been reported. Using these techniques, the input voltage swing of circuits can be extended due to the threshold voltage that can be reduced or removed from the signal path.

In this work, the dynamic threshold technique has been used to realize a new extremely low-voltage, low-power OTA (DT-OTA) for low-frequency bio-signal processing. The proposed OTA has been used to realize a bandpass filter (BPF) with adjustable gain for ECG signal processing. The voltage gain and higher cutoff frequency can be controlled.

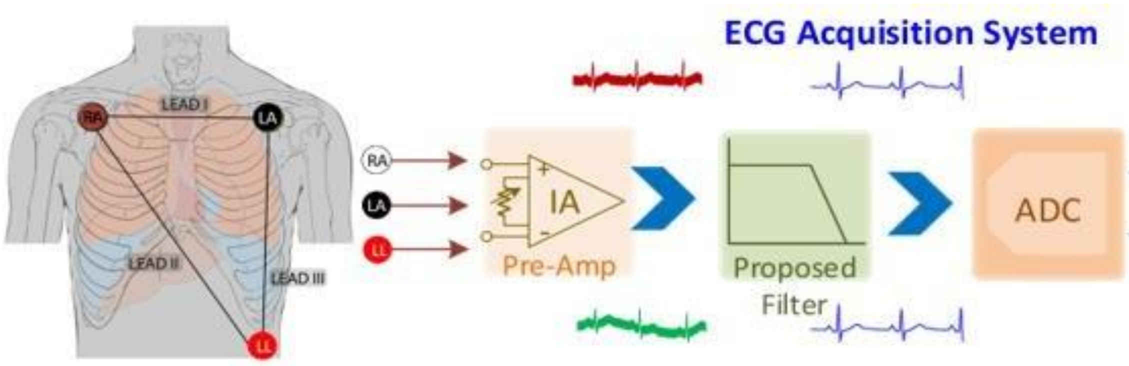

Fig 1.1: ECG Acquisition System [9]

- An electrocardiogram (ECG or EKG) records the electrical signal from the heart to check for different heart conditions.
- Electrodes are placed on the chest to record the heart's electrical signals, which cause the heart to beat. The signals are shown as waves on an attached computer monitor or printer.

Frequency Range: A healthy ECG signal typically falls within a frequency range of **0.05 Hz to 50 Hz**. This range can be further divided into components associated with specific cardiac activities:

- **P wave (0.67–5 Hz):** represents atrial depolarization, the initiation of electrical activation in the atria.
- **QRS Complex (10–50 Hz):** corresponds to ventricular depolarization, the rapid spread of electrical activation through the ventricles, responsible for the main peak in the ECG waveform.
- **T Wave (1–7 Hz):** Reflects ventricular repolarization, the recovery of the ventricles to their resting state.

- The electrocardiogram (ECG), a cornerstone of cardiology, offers a painless assessment of heart function through recording its electrical activity. This non-invasive test translates the heart's electrical impulses into a recognizable waveform with P, QRS, and T waves, each corresponding to specific stages of a heartbeat. Analysis of this waveform allows healthcare professionals to diagnose a wide range of heart conditions, including arrhythmias that disrupt rhythm, conduction abnormalities affecting electrical signal transmission, myocardial ischemia indicative of potential heart attacks, and heart chamber enlargement that can signal heart failure.

1.2 FILTERS

OTA-based filters offer a powerful alternative to traditional passive filters. These active filters utilize Operational Transconductance Amplifiers (OTAs) as building blocks, overcoming limitations like size and fixed characteristics. OTAs provide compactness, electronic tunability, and improved performance. Research in this area explores various filter types (low-pass, high-pass, etc.) and design techniques, aiming to optimize filter parameters like cut-off frequency and power consumption. This thesis delves into designing a specific type of OTA-based filter (e.g., low-power band-pass filter) using chosen design methodologies and explores its performance through simulations and potentially real-world testing.

The types of filters are:

- Low-pass filter (LPF): allows low frequencies to pass through while attenuating high frequencies.
- High-pass filter (HPF): passes high frequencies while blocking low frequencies.
- Band pass filter (BPF): only allows a specific band of frequencies to pass through, rejecting other frequencies.
- Band stop filter (BSP): Block certain specific bands of frequencies while allowing others to pass.

1.2 OPERATIONAL TRANSCONDUCTANCE AMPLIFIER

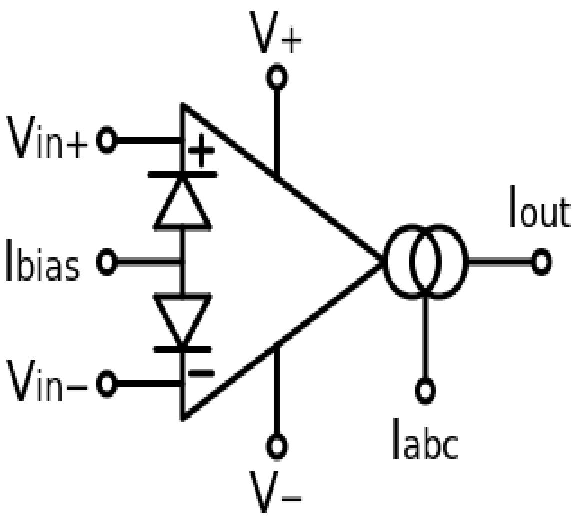

Fig 1.2: Operational Transconductance Amplifier [10]

The Operational Transconductance Amplifier (OTA) plays a crucial role in various analog circuits, especially filters. Unlike its counterpart, the operational amplifier (op-amp) that amplifies voltage, an OTA functions as a voltage-controlled current source (VCCS). This means it translates a differential input voltage into a proportional output current.

An OTA's internal structure typically consists of a differential input stage that receives the voltage, a gain stage for amplifying the voltage, and an output stage for buffering the resulting current and providing a high-impedance output. The gain stage often utilizes transistors to convert the voltage into a proportional current. Key parameters of an OTA include transconductance (gm), bandwidth, and Common-Mode Rejection Ratio (CMRR). Understanding these parameters and the OTA's working principle is essential for designing efficient and tunable filters that leverage the advantages of OTAs, such as compactness, tunability, and ease of integration with other circuits.

An operational transconductance amplifier (OTA) is a versatile building block in analog electronics. Unlike a typical op-amp that amplifies voltage, an OTA excels at converting a voltage difference at its input into a proportional current output.

Imagine the OTA as a variable current source controlled by voltage. The voltage difference between its input terminals dictates the amount of current it allows to flow through its output. A larger voltage difference translates to a higher output current.

This unique ability makes OTAs valuable in various applications. They are ideal for current-controlled circuits like LED drivers and actuator controls. Their current-handling properties are also useful in signal processing circuits like filters and analog-to-digital converters. In some cases, OTAs can even be incorporated into feedback circuits for voltage amplification.

1.3 OBJECTIVES OF THE WORK

- To design a low pass filter using low power OTA.

1.4 OVERVIEW OF THE PROJECT

- To design and implement low pass filter using low power ota with less number of transistors using 180nm technology.

1.5 CONTRIBUTION OF THE THESIS

- This thesis represents the work done related to 180nm technology. We require a cadence virtuoso tool for the simulation of the related work.

CHAPTER 2

LITERATURE SURVEY

Electrocardiogram (ECG) is a vital medical signal that provides valuable insights into heart health. However, ECG signals are often contaminated with high-frequency noise and interference, which can obscure the underlying physiological information. Low-pass filters play a crucial role in ECG signal processing by attenuating these unwanted signals and extracting the ECG signal of interest.

2.1 BULK DRIVEN OPERATIONAL TRANSCONDUCTANCE AMPLIFIER

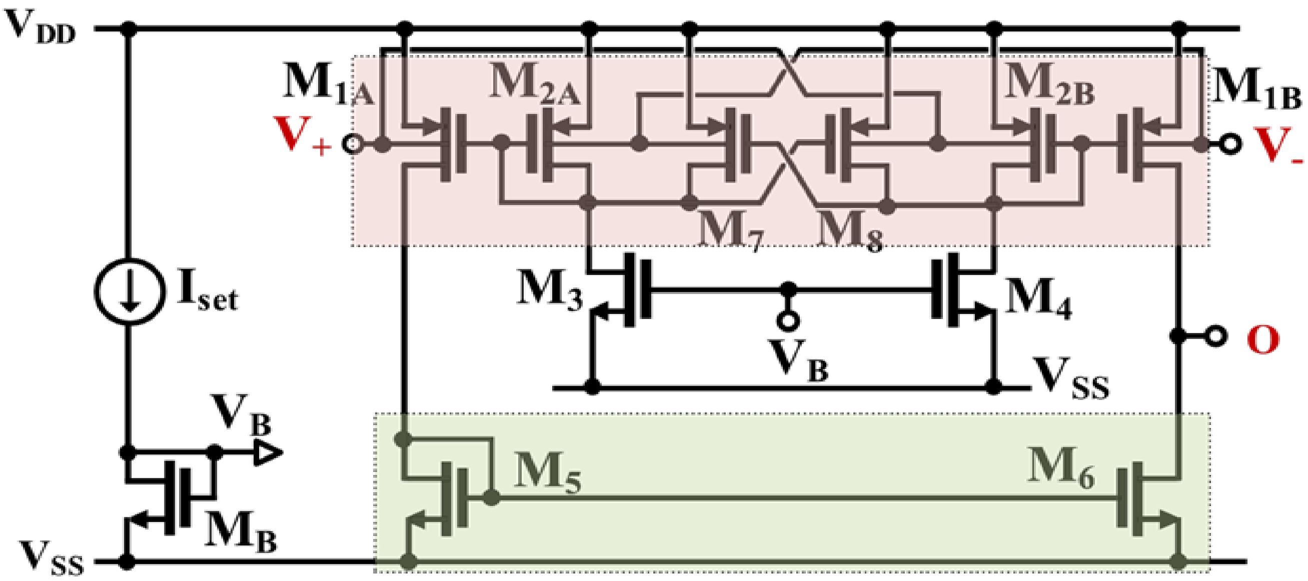

Fig 2.1: Bulk driven OTA [11]

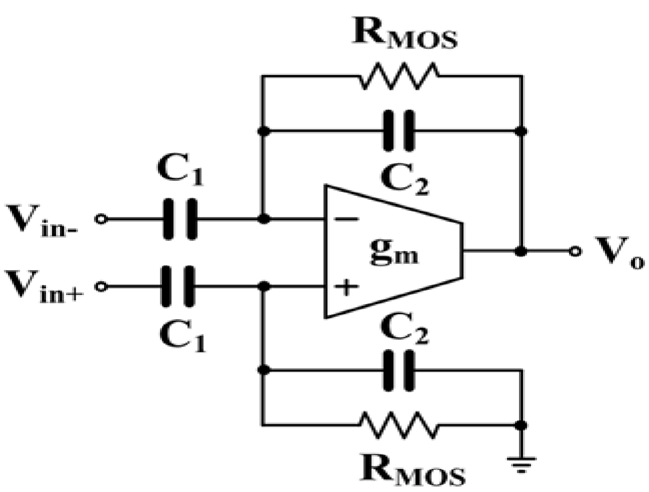

Fig 2.1.1: Band pass filter Circuit [11]

2.1.2 WORKING

The CMOS schematic of the 0.5-V OTA used to realize the BPF proposed in this project is shown in Fig. 2.1. This circuit is designed to serve as the input stage of a two-stage operational amplifier. Here, the structure is used as a single-stage amplifier, with all transistors replaced by self-composite devices. The OTA shown in Fig. 1a is in fact a single-stage nontailed differential amplifier. For simplicity, let us first consider the version with transistors M7 and M8 removed. In such a case, transistors M1A with M2A and M1B with M2B form two current mirrors. The mirrors are biased with constant current sources based on transistors M3 and M4.

The input differential signals V+ and V− are applied to the bulk terminals of the input transistors. With V+ = V−, the threshold voltages of M1A and M2A (M1B and M2B) are equal for every level of the input voltage. Therefore, neglecting the impact of drain-source conductance's gds, the current gains of the above-mentioned current mirrors do not depend on the input common-mode signals. Note that in such a case, the drain currents of M1A and M1B are not only equal but also remain constant and equal to the biasing currents ID3,4.

This is a significant difference in comparison with pseudodifferential amplifiers, where the currents of a differential stage highly depend on the common-mode level. The drain currents of M1B and M1A (ID1B and ID1A) are subtracted thanks to the unity-gain current mirror M5-M6; thus, the output current is equal to zero. Note that, neglecting second-order effects, variations of VDD do not affect the drain currents of M1A and M1B. Thus, neglecting the impact of second-order effects, the output signal of the OTA is insensitive to both the input common-mode level and variations of VDD.

This results in relatively large values of the common-mode and power supply rejection ratios (CMRR and PSRR, respectively). When V+ and V− are not equal, then the threshold voltages of M1 and M2 are different, thus producing a current difference between M1 and M2 and consequently a non-zero output current for the whole stage. Note that the value of this current is not limited by a tail current source and can approach significant values, much larger than the biasing currents ID3, 4, and 5. This improves the slew rate (SR) of the OTA.

By removing the tail current source, which is used for biasing the differential amplifiers in conventional solutions, the minimum VDD can be decreased while still offering good CMRR and PSRR performances. This also increases the output swing of the OTA, which is nearly rail-to-rail.

By applying a single-stage OTA, a power-effective solution can be achieved as it eliminates the need for a second gain stage that usually consumes more power. However, sufficient voltage gain is problematic. In order to increase the voltage gain, two additional techniques have been applied. First, the voltage gain is increased by applying partial positive feedback (PPF), introduced by the cross-coupled transistors M7 and M8. The transistors generate negative conductances at the drain and gate nodes of M2A and M2B, thus increasing the resulting resistance at these nodes and consequently increasing the voltage gain from the input terminals to these nodes. Since transistors M1A and M1B are controlled with larger signals at their gates, the overall transconductance and the voltage gain of the OTA are increased.

2.2 DYNAMIC THRESHOLD MOS OTA:

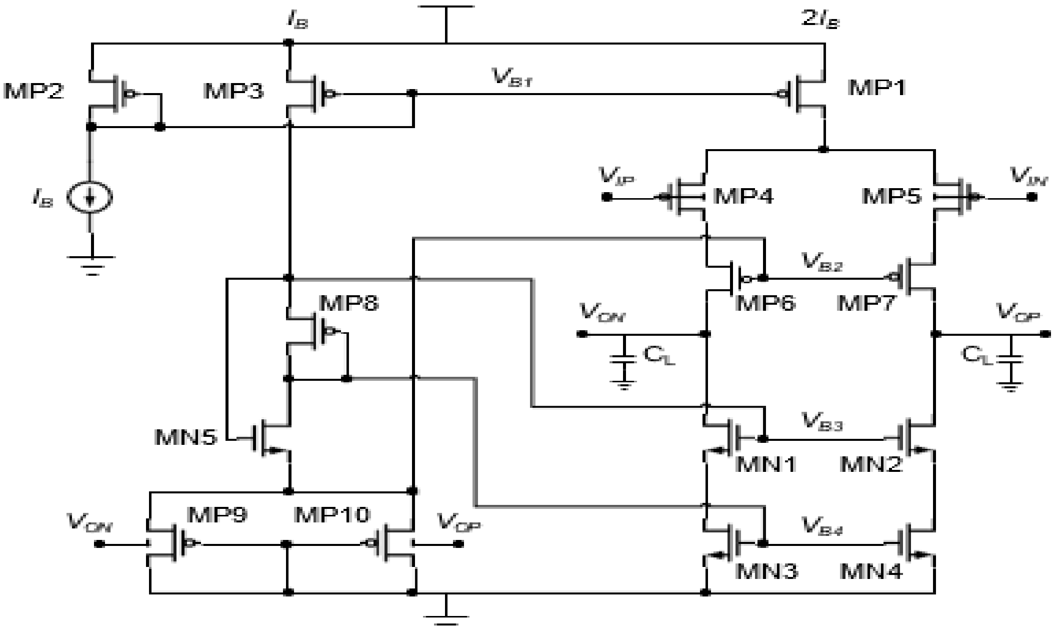

Fig 2.2: DT-MOS OTA [12]

2.2.2 WORKING

The OTA with bias and CMFB circuit is shown in Fig. Firstly, the body connections of the transistors in the circuit should be noted. The input pair MP4 and MP5 are DTMOS transistors, their bodies are connected to their respective gates. MP9 and MP10 work as bulk-driven CM sensors, their bodies are connected to the differential outputs of the OTA, V_{OP} and V_{ON}.

Telescopic OTA has the advantages of power efficiency and high speed, while its main disadvantages are the limited output swing and input CM range. What's more, in some circuit topologies such as unity-buffers and switched-capacitor circuits, the input and output of the OTA would be shorted for part of the operation period. In low supply voltage, it is very hard for a telescopic OTA to short its input with the output. The input CM range and single end the output swing is only 0.25 V. In addition, the input and output range are not overlapped, making the OTA cannot be used in systems requiring the input and output to be shorted.

This problem will be solved by using DTMOS input differential pair. According to Fig. 1, the threshold voltage of a PMOS-based DTMOS transistor is largely reduced by the forward bias voltage between the source and body. When the DTMOS transistors are biased at the source-gate voltage of 0.5 V, their threshold voltage will be reduced to about 0.3 V.

The bias voltages of the OTA are provided by a very concise bias circuit, which only contains two current branches. The bias voltage V_{B1} is generated by the reference current I_B flowing through a diode connected PMOS transistor MP2.

The bias voltages V_{B3} and V_{B4} can be self-regulated by the negative feedback loop formed by MN5 and MP8, making the OTA robust against the variations of fabrication and working conditions. If there are some variations cause V_{B3} increase, V_{B4} will also increase through the diode connected transistor MP8, and then the channel-length modulation effect of MN5 will pull down its drain voltage ,i.e.,VB3

In fully differential analog architectures, the CMFB plays a critical role in bias stabilization. A CMFB is often used to improve the CM rejection ratio (CMRR) of the OTA. In this work, a new bulk-driven CMFB circuit is designed and embedded in the bias circuit. The differential outputs V_{ON} and V_{OP} are applied to the bodies of two PMOS transistors MP9 and MP10 respectively. When the output CM voltage increases, the variation is detected by the bulk-driven transistors MP9 and MP10. The differential mode signal is cancelled and the increase in the CM voltage causes V_{B2}, V_{B3} and V_{B4} to rise, thus in turn, pull the output CM voltage down.

2.3 FULLY DIFFERENTIAL TWO-PHASE DT-MOS OTA

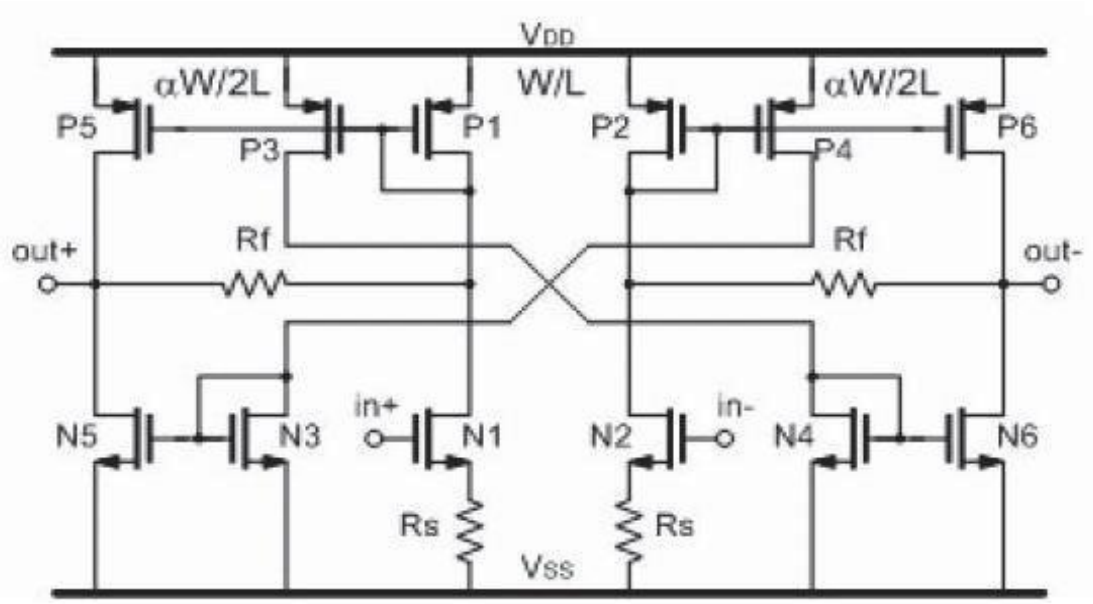

Fig 2.3: Circuit diagram Two phase cascade variable gain amplifier [13]

2.3.1 WORKING

A differential input voltage creates an output current in an OTA. Two-phase OTA is a essential aspect of LNA. It ispreferred over single-ended output as it has huge swing and is noise-free. Fully differential OTA consists of 11 maintransistors in that there are 6 PMOS and 6 NMOS transistors with each transistor performing a specific function. It features both differential inputs and differential outputs.

Shows circuit diagram of two phase cascade variable gain amplifier. The proposed Variable gain amplifier is mixture of a current mode transimpedance amplifier (P1-P6, N3-N6) and a source degradation differential transconductance amplifier (N1-N2, Rs) so as to maximise bias current efficiency, transconductance, and also minimise the voltage as well as noise. DC current sources are commonly implemented by using cascaded current mirrors. Common mode signals cannot be discarded by such structures, which is significant drawback.

The feed forward method by the mirror based second stagecurrent amplifier (P1-P6, N3-N6) helps to solve this issue by allowing two differential signals to be constructively blended while cancelling common mode signals. When a current amplifier is coupled with a feedback resistance

(Rs), a transimpedance amplifier is formed, which is necessary for current to voltage conversion. In compared to ascendant provided in [14], this output stage also allows for class AB functioning of the electronics components and allows for greater signal swing. As a result, the major feature of such circuits of VGA is its ability to provide excellent signal linearity while maintaining original benefits of low power consumption and circuit clarity.

CHAPTER 3

CIRCUIT PARAMETERS

Over the past several years, silicon CMOS technology has become the dominant fabrication process for relatively high-performance and cost-effective VLSI circuits. The revolutionary nature of these developments is understood by the rapid growth in the number of transistors integrated on a single chip.

The electronics industry has achieved phenomenal growth over the last few decades, mainly due to the rapid advances in large-scale integration technologies and system design applications. With the advent of very large-scale integration (VLSI) designs, the number of applications of integrated circuits (ICs) in high-performance computing, controls, telecommunications, image and video processing, and consumer electronics has been rising at a very fast pace.

The main parameters of the circuit to be considered in the project are Gain, Bandwidth, CMRR and Noise.

3.1 GAIN

Gain can be used to increase the power of a signal. For example, if we want to amplify a weak signal, we can use an amplifier with a high gain. Gain can also be used to decrease the power of a signal. For example, if we want to attenuate a strong signal, we can use an amplifier with a low gain.

In electronics, gain refers to an amplifier's ability to increase the strength of a signal. It's essentially a measure of how much the amplifiers boost the signal's amplitude (voltage or current) or power. There are different types of gain depending on what aspect of the signal is being amplified: voltage gain, current gain,and power gain.

3.2 BANDWIDTH

Bandwidth in amplifiers refers to the range of frequencies an amplifier can amplify effectively. Imagine a signal as a combination of musical notes, each with a specific frequency. An amplifier boosts the signal's strength, but its ability to do so weakens as frequencies deviate from a central range. This defines the bandwidth limitations

Bandwidth is crucial for amplifier design. An audio amplifier for human hearing (20 Hz to 20 kHz) needs a flat bandwidth within this range to preserve sound quality. Conversely, radio frequency (RF) amplifiers for communication systems target specific frequency bands and are designed accordingly.

3.3 CMRR

Amplifiers deal with amplifying a desired signal while minimizing unwanted electrical noise. The Common Mode Rejection Ratio (CMRR) quantifies an amplifier's ability to suppress this noise. CMRR focuses on common-mode signals, which appear identically on both amplifier inputs. This noise can be external interference or internal circuit noise. Ideally, only the differential signal (the difference between the two inputs) gets amplified.

A high CMRR amplifier effectively cancels out common-mode noise, resulting in a cleaner output. This is crucial for applications with weak desired signals or high noise environments, like sensor measurements and high-fidelity audio systems. CMRR is specified in decibels (dB) with higher values indicating better noise rejection.

3.4 NOISE

Noise in amplifiers refers to any electrical signal that disrupts the desired input signal. It can come from external sources like radio waves or from within the amplifier itself due to thermal or electrical current fluctuations. This unwanted noise can distort or weaken the amplified output, reducing its fidelity and accuracy.

Minimizing noise in amplifiers is crucial for optimal performance. Careful circuit design and component selection can help reduce internal noise generation. Shielding the amplifier with a metal enclosure protects it from external electromagnetic interference. Filters can target and eliminate specific noise frequencies, while a high CMRR amplifier effectively cancels out noise that appears equally on both inputs.By understanding noise sources and implementing these mitigation techniques, we can design amplifiers that deliver clean, accurate signals.

CHAPTER 4

SOFTWARE TOOLS USED

4.1 CADENCE VIRTUOSO

View other drafts Cadence Virtuoso is a comprehensive suite of electronic design automation (EDA) tools used for integrated circuit (IC) design and verification. It provides a wide range of capabilities for designing, simulating, and laying out ICs, from small analog circuits to complex digital systems. Virtuoso is a popular choice for IC designers due to its powerful features, ease of use, and wide industry support.

The purpose of Cadence Virtuoso is to enable engineers to: Design and verify integrated circuits (ICs) Create high-performance, reliable ICs Meet the stringent requirements of IC manufacturing Design ICs for a wide range of applications, including consumer electronics, medical devices, and automotive systems Virtuoso is used in all stages of the IC design process, from initial schematic capture to final layout verification.

It includes tools for: Schematic capture: Creating and editing circuit schematics Simulation: Simulating circuit behavior to verify functionality and performance Layout: Placing and routing transistors and other components on the chip Verification: Checking the layout for design rule violations and ensuring that it meets all electrical and timing requirements Virtuoso is also integrated with a variety of other EDA tools, such as Cadence's IC Compiler and Design Compiler, to provide a complete IC design flow.

This allows designers to seamlessly transition between different stages of the design process and use the best tools for each task. Here are some of the key benefits of using Cadence Virtuoso: Increased productivity: Virtuoso's ease of use and powerful features can help designers to create ICs more quickly and efficiently. Improved design quality: Virtuoso's comprehensive verification tools can help to ensure that ICs meet all electrical and timing requirements. Reduced time to market: Virtuoso can help to reduce the time it takes to bring ICs to market. Lower development costs: Virtuoso can help to reduce the cost of developing ICs.

Overall, Cadence Virtuoso is a valuable tool for IC designers who want to create high-performance, reliable ICs quickly and efficiently. In addition to the above, here are some specific examples of how Cadence Virtuoso is used: Analog IC design: Virtuoso is used to design a wide range of analog ICs, including operational amplifiers, filters, and voltage regulators.

4.1.1 180nm Technology

180nm technology is a semiconductor manufacturing process that uses transistors with a gate width of 180 nanometers (nm). This technology was first commercialized in the late 1990s and is now considered to be a mature process. It is still used for a wide range of applications, including microprocessors, microcontrollers, and memory chips. 180nm technology transistor Opens in a new window 180nm technology transistor The 180nm process uses a number of advanced techniques to achieve its high performance and density.

These techniques include: Deep trench isolation: This technique uses deep trenches to isolate transistors from each other, which helps to reduce leakage current. Copper interconnects: Copper has a lower electrical resistance than aluminum, which is used in older processes. This helps to improve the performance of the circuits. Low-k dielectric: This is a type of dielectric material that has a low dielectric constant. This helps to reduce the capacitance of the interconnects, which improves the speed of the circuits. The 180nm process is a very versatile process that can be used to manufacture a wide range of circuits. It is a cost-effective process that can be used to produce high-performance circuit.

CHAPTER 5

PROPOSED WORK

The proposed system introduces a new BPF using low-voltage and low-power OTA. The OTA is realized using BD MOS and DT-MOS [15][16][17] operating in the sub-threshold region, and thus, it can work with 0.5 V. The circuit is supplied at only 0.5 volts, and a wide input range can be obtained with a compact structure. The structure was designed in the Cadence program using 0.18 μm CMOS technology. The proposed BPF can be applied for low-frequency applications like biomedical signals, such as local field potential, electroencephalograms, and electrocorticography. The proposed low-pass filter can remove the noise, and the band-pass filter can also reduce the low-frequency motion artifact from ECG signals.

5.1 CIRCUIT DIAGRAM OF OTA

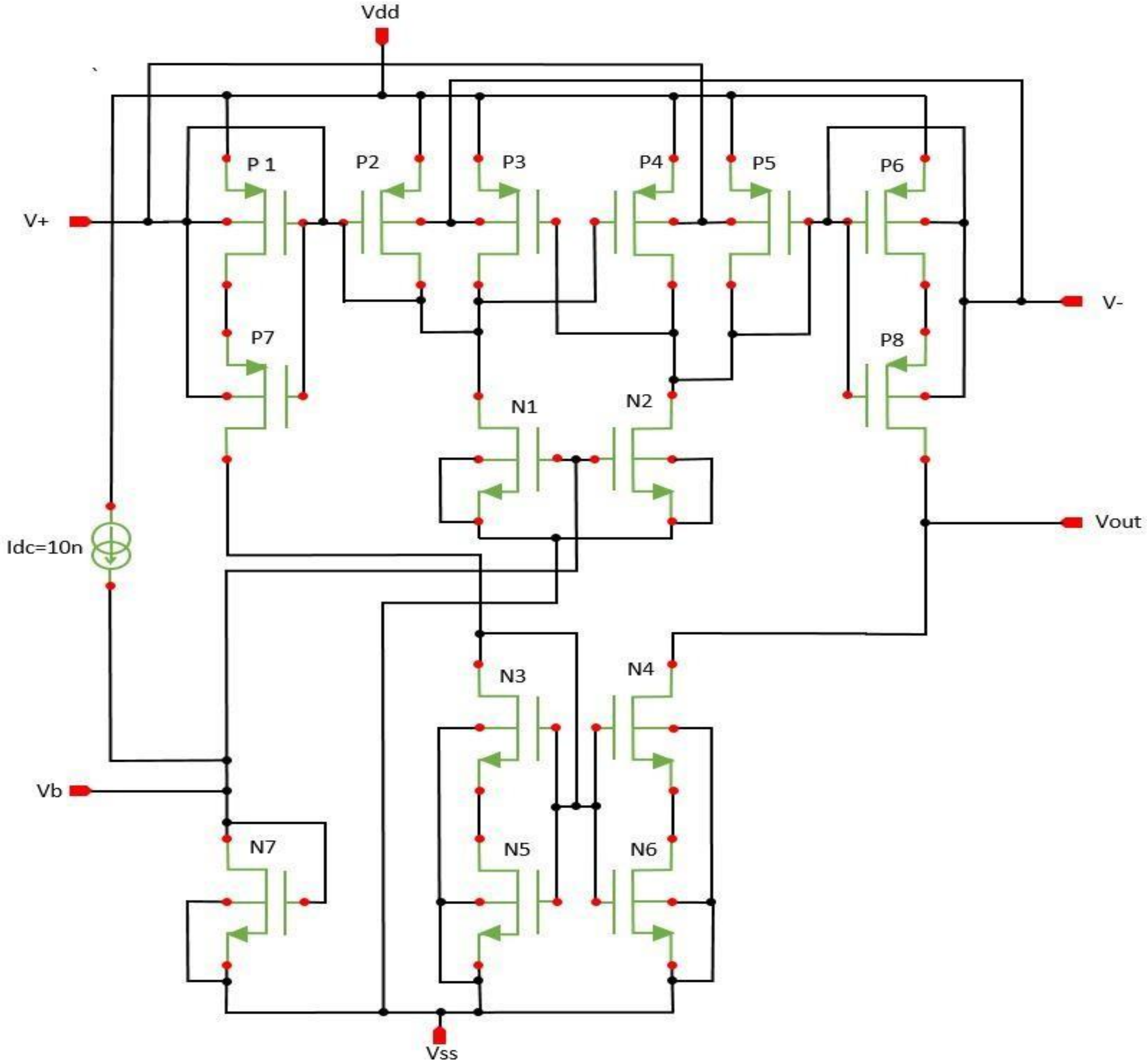

Fig 5.1: Proposed OTA

5.1.1 CIRCUIT DIAGRAM OF FILTER

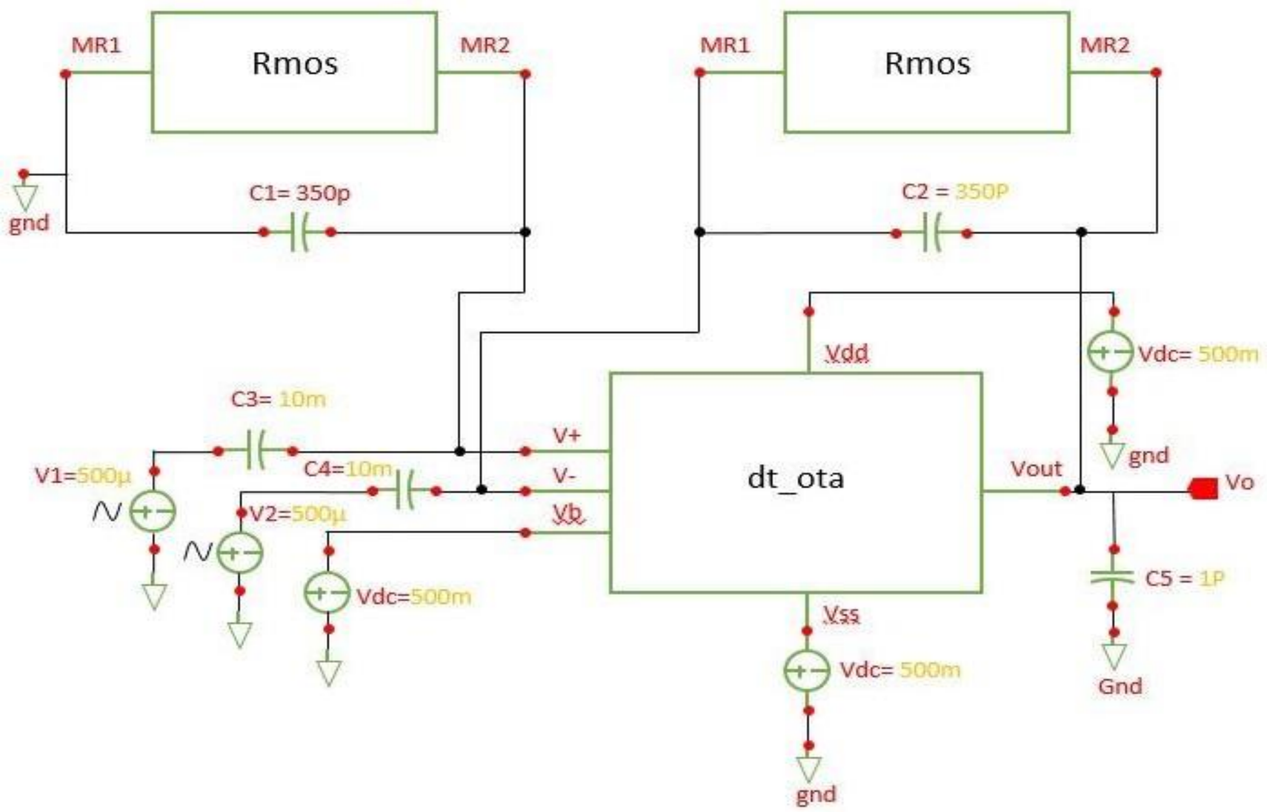

Fig 5.1: Proposed Filter

5.2.1 WORKING OF OTA

The proposed circuit diagram is realised and verified experimentally using the Dynamic Threshold MOS(DT-MOS) technology and current mirror architecture. We have used the IEEE 1801-2009/2018 for designing the circuit. The current mirror OTA design relies on current mirrors to control the output current. The main function of this archiecture is to copy a current from input stage to output stage. It takes a differential input voltage and amplify in proportional to the output current.

A Dynamic Threshold MOS (DT-MOS) is a type of Metal Oxide Semi-Conductor Field Effect Transistor (MOSFET) designed to have a dynamic threshold. This means that the threshold voltage can be controlled by the body terminal which helps the Metal Oxide Semi-Conductor Transistor

(MOST) to operate in the weak inversion region as well. The simplest way of using the dynamic threshold technique is by shorting the body and gate of the transistor.

The circuit uses two methods to improve the gain which are Self cascade technique used at the input transistors(P1,P3 and P6,P8) and Partial positive feedback(PPF) which is achieved by cross-coupled feedback transistors (P3,P4).

The self cascode technique helps in significant improvement of the gain as it is a stacking of two transistors which results in higher output when compared with the single transistor circuit. PPF also known as the regenerative feedback, it is a process in which the part of output is fed back to the input. In the above circuits the P3,P4 transistors are used as a cross-coupled feedback.

5.2.2 WORKING OF FILTER

The Low pass filter(LPF) has been realised using the proposed Dynamic threshold operational transconductance amplifier and a RC network. This second order filter uses a resistor which is designed by cascading the 2 nmos transistors. The low pass filter a range of frequencies and attenuate all other frequencies. The C1,C2 used at the RC network and the C3,C4 transistors are used to eliminate the dc offset voltage.

The cutoff frequency of the circuit is calculated with the help of Resistance and capacitance used in the circuit i.e., Rmos, C1,C2. The C5 is the load capacitance. The filter supplied with a 0.5 Volts supply. The Low pass filter has a gain of 57.8dB and cutoff frequecy of 350Hz with a gain bandwidth product of 20230.

This filter can be used for the bio-signal applications such as ECG-signals and filter them, which helps for the better analysis of the signal. The IEEE 11073 are used in the designing of the filter for particular range of frequencies.

5.3 SIMULATION RESULTS

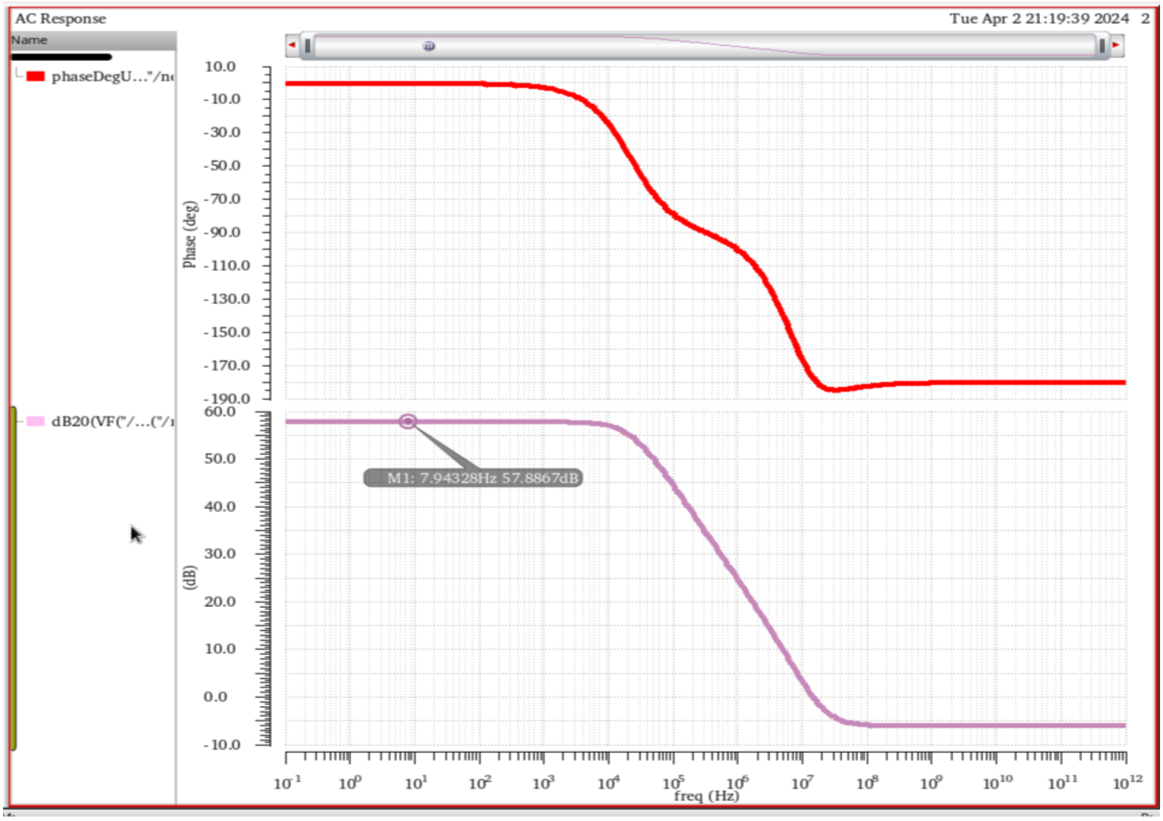

Fig 5.3.1: OTA's Gain VS Freq plot

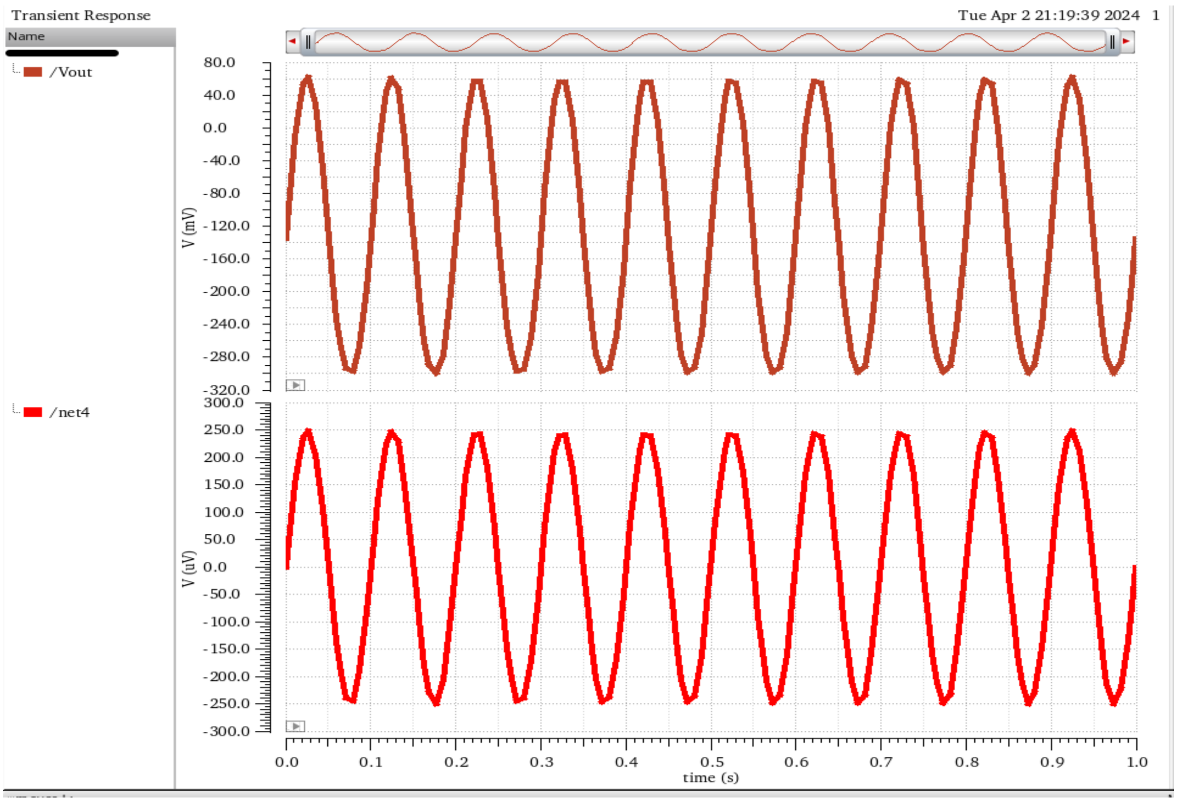

Fig 5.3.2: Transient Response

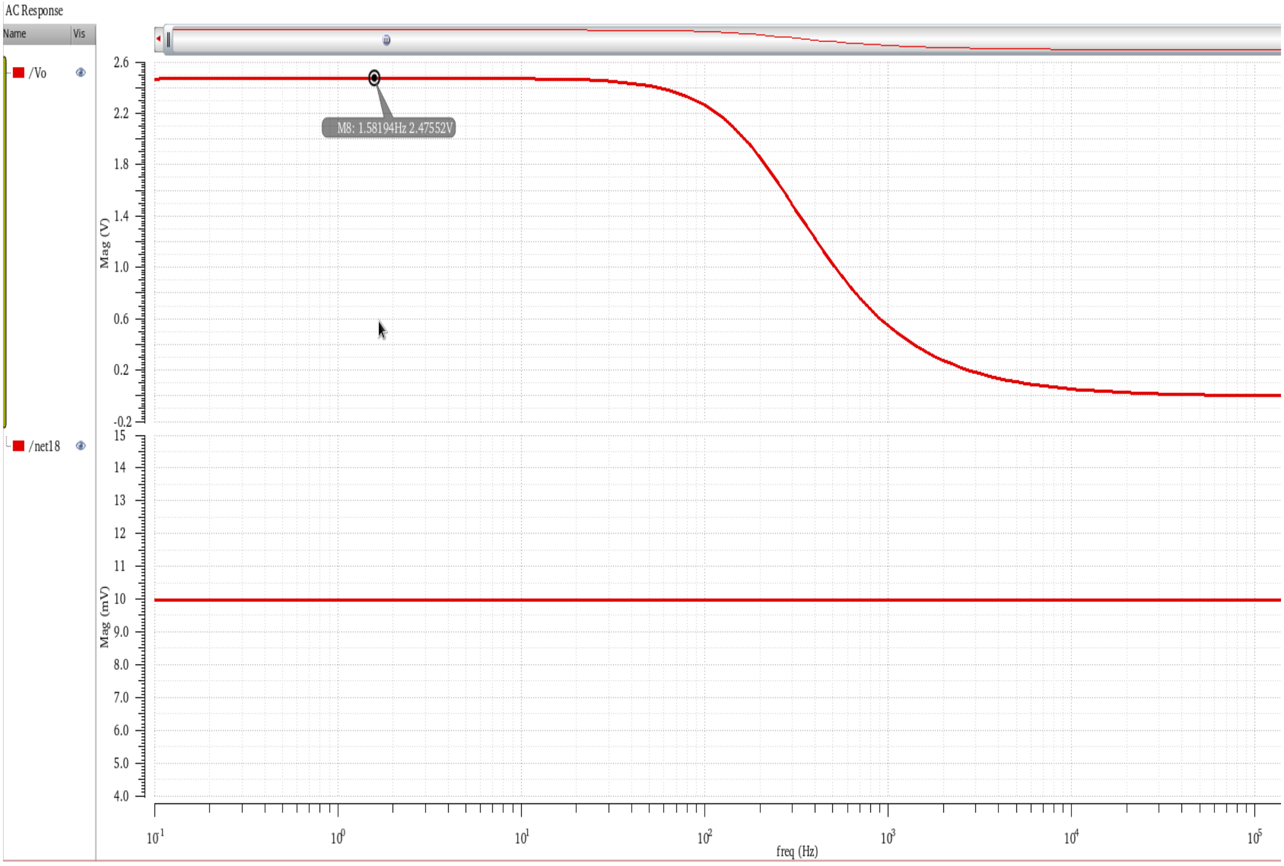

Fig 5.3.3: AC Response

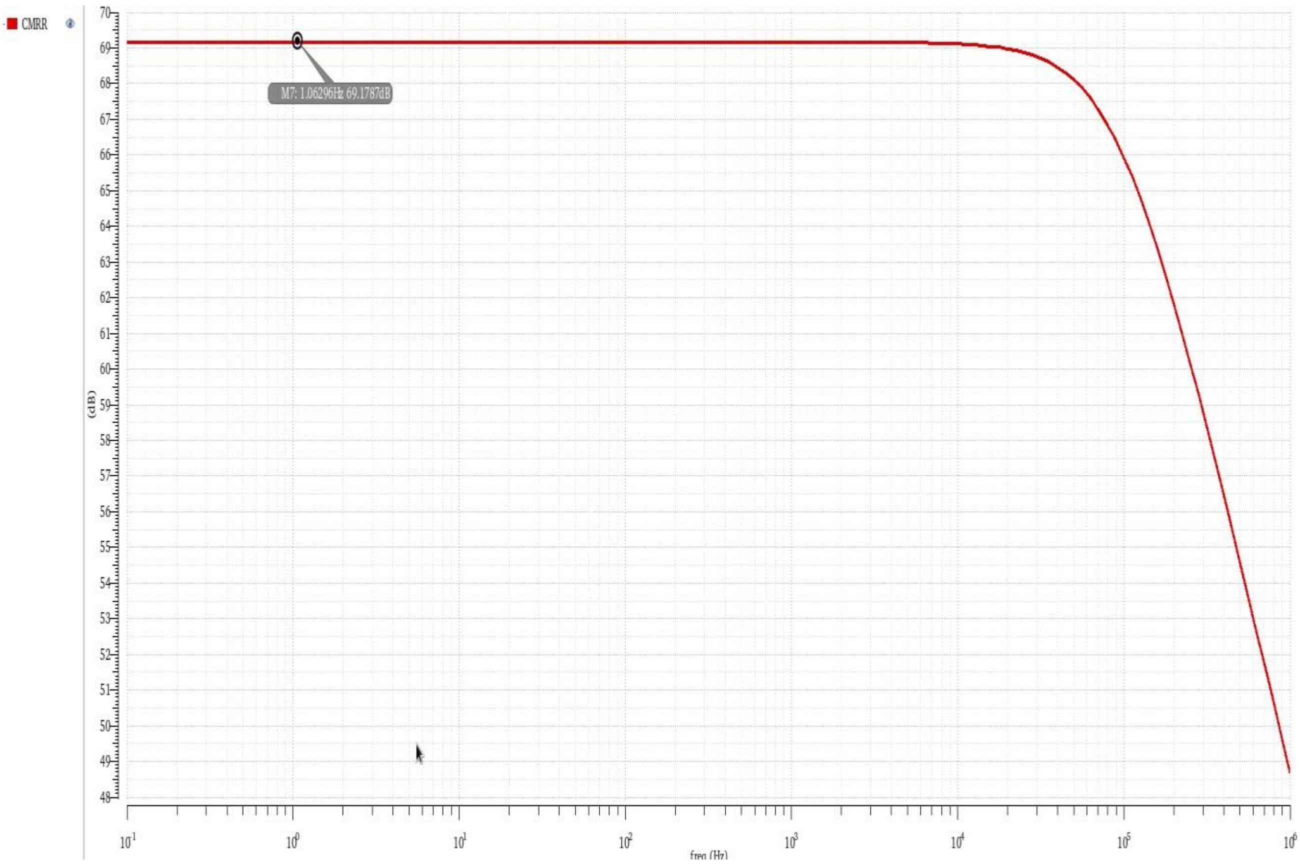

Fig 5.3.4: Common Mode Rejection Ratio

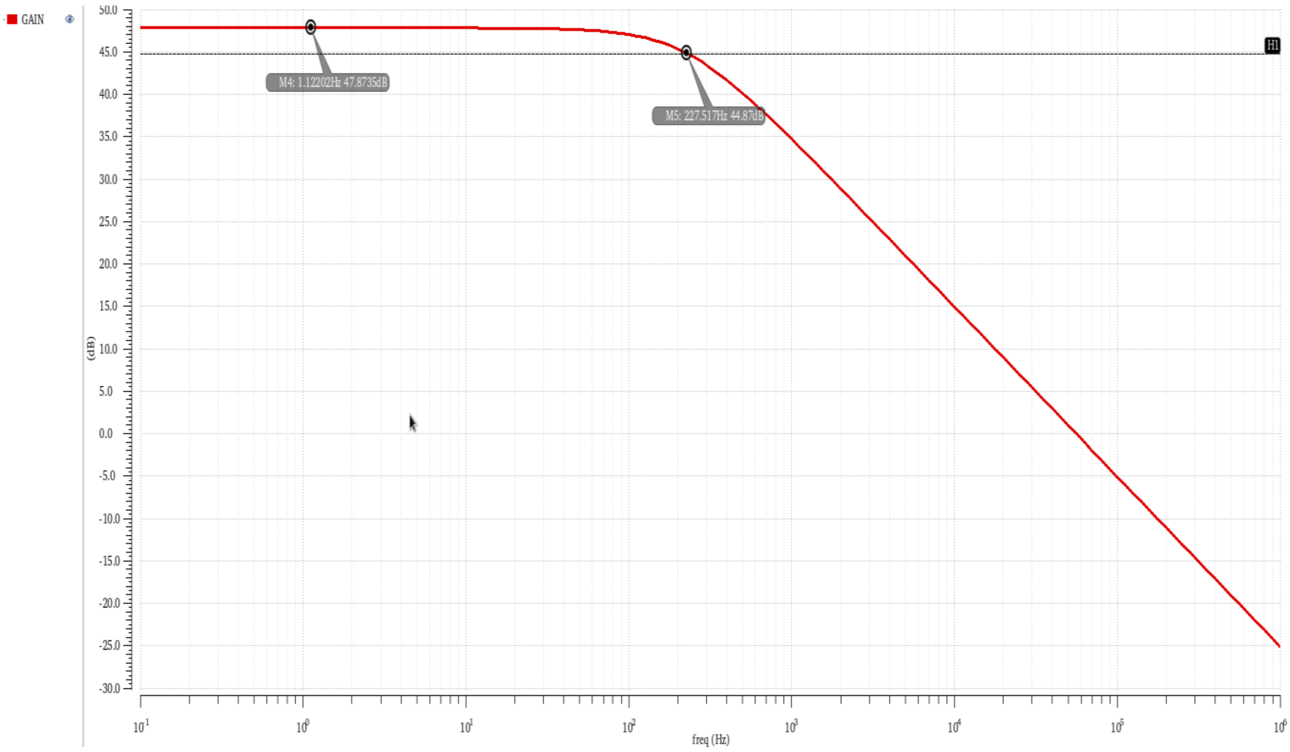

Fig 5.3.5: Gain

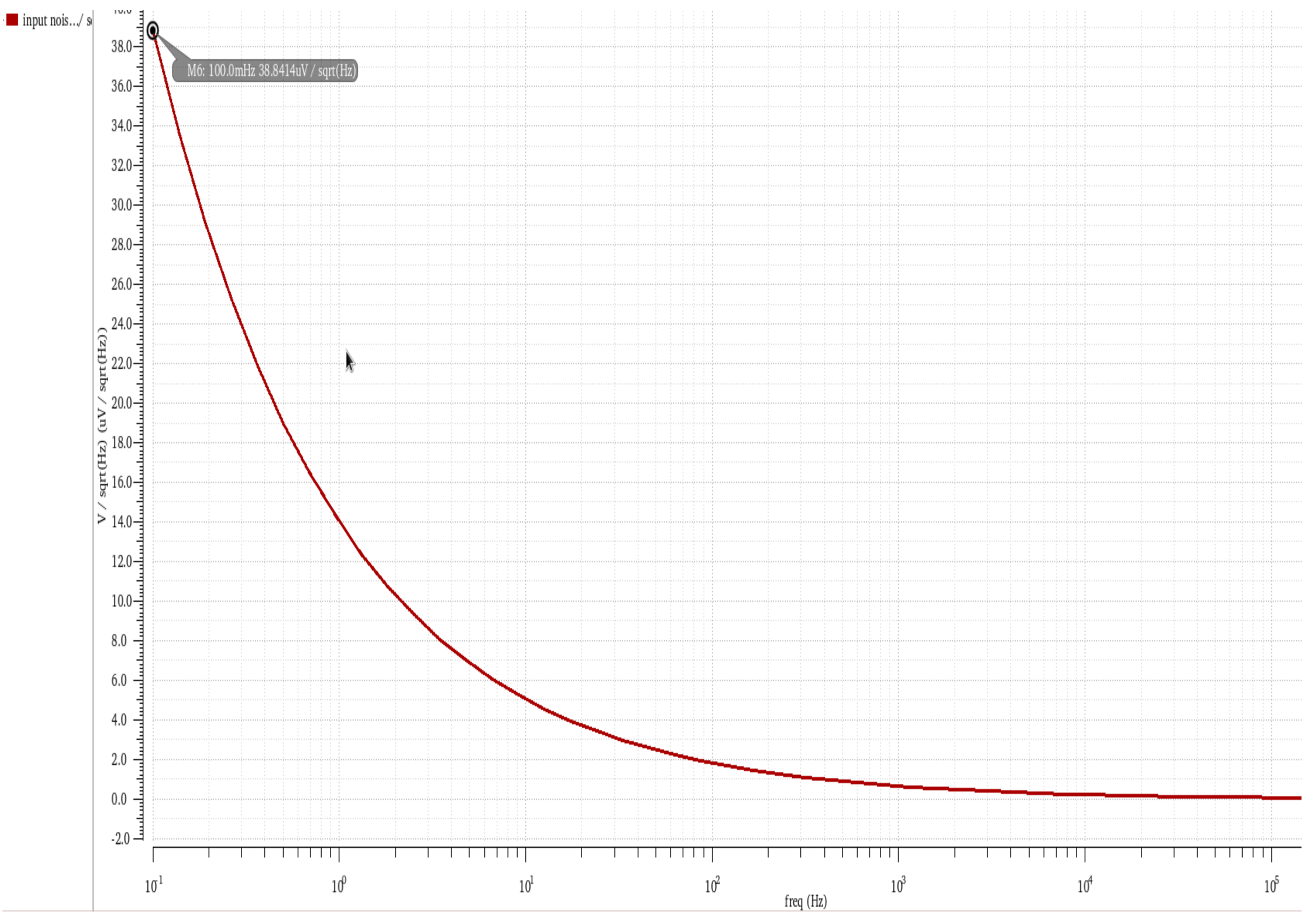

Fig 5.3.6: Input referred Noise

5.4 COMPARITIVE ANALYSIS

Table.5.4.1: Comparison of Proposed OTA with previous works

S.no	Title	Gain (dB)	Circuit Technology	Operating Voltage	Technology
1.	31.3nW, 0.5V Bulk driven OTA for Biosignal Processing	37	Bulk-Driven	0.5	180nm
2.	Low Power Low Pass OTA based RC Active Filter	8	Gate-Driven	1	180nm
3.	Low Power OTA with Series-Parallel current mirror for low freq Gm-C Filters	55	Bulk-Driven	0.5	180nm
4.	DTMOS -Based Fully Differential Telescopic OTA	64	DT-MOS	1.8	180nm
5.	Design of Low-Pass Filter using OTA for Bio-Signal Acquisition	57.8	Bulk-Driven DT-MOS	0.5	180nm

Table.5.5.2: Comparison of Proposed Filter with previous works

S.no	Title	Gain (dB)	Order	Operating Voltage	Bandwidth (Hz)
1.	31.3nW, 0.5V Bulk driven OTA for Bio-Signal Processing	42	2	0.5	1.5-112
2.	Low Power Low Pass OTA based RC Active Filter	10	1	1	0.1-70
3.	Low Power OTA with Series-Parallel current mirror for low freq Gm-C Filters	44	3	0.5	32-263
4.	DTMOS -Based Fully Differential Telescopic OTA	64	1	1	0-2.8k
5.	Design of Low-Pass Filter using OTA for Bio-Signal Acquisition	47.8	2	0.5	0-230

CHAPTER 6

ADVANTAGES DISADVANTAGES AND APPLICATIONS

6.1 Advantages

- **High performance**: Circuits manufactured using 180nm technology can operate at very high speeds.
- **Low power consumption**: Circuits manufactured using 180nm technology can operate at very low power levels.
- **High density**: Circuits manufactured using 180nm technology can pack a lot of transistors onto a small chip.
- **Cost-effective**: 180nm technology is a mature process that is relatively inexpensive to manufacture.

6.2 Disadvantages

- **Large feature size**: The 180nm feature size is relatively large by today's standards. This means that circuits manufactured using 180nm technology cannot pack as many transistors onto a chip as circuits manufactured using newer processes.
- **Limited performance**: Circuits manufactured using 180nm technology cannot operate at as high speeds as circuits manufactured using newer processes.
- **Complexity:** OTA **-**based filter can be complex to design than traditional op amp based filters.

6.3 Applications

- **ECG**: Electrocardiography (ECG) is a noninvasive medical procedure that records the electrical activity of the heart over time using electrodes placed on the surface of the skin. The four-chambered muscular pump that moves blood throughout the body.
- **Audio signal processing**: Audio signal processing is a subfield of electrical engineering that deals with the manipulation of audio signals. Audio signals are electronic representations of sound waves - longitudinal waves which travel through the air, consisting of the compressions and rarefactions. The energy contained in audio signals or sound power level is typically measured in decibels.

- **Communication Systems**: Communication systems are the backbone of modern society, enabling the exchange of information between people, devices, and machines. They play a crucial role in various aspects of our lives, from personal interactions to global networks.

Understanding the fundamental principles of communication systems is essential for designing, analyzing, and optimizing their performance.

- **Instrumentation**: Instrumentation is the art and science of measuring and controlling physical quantities. It encompasses a wide range of disciplines, including physics, chemistry, engineering, and mathematics. Instrumentation plays a vital role in various industries, from manufacturing and process control to scientific research and medical diagnostics.

- **Power Supply Filtering**: Power supply filtering is the process of removing unwanted noise and fluctuations from a power supply. This is necessary because electronic devices are sensitive to variations in the power supply voltage, which can cause them to malfunction or produce erroneous results.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

This work presents a new BPF using low-voltage and low power OTA. The OTA is realized using bulk driven technology; thus, it can work with 0.5 V of voltage supply and has low power consumption. The structure was designed in the Cadence using 0.18 μm CMOS technology files. The simulated results agree with the theoretical analysis. The proposed BPF can be applied to the biomedical signals.

7.2 FUTURE SCOPE

- Can be further implemented using latest Node technologies.

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