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ACTIVE LOW PASS FILTER FOR BIOMEDICAL APPLICATIONS

M.Renuka[*1], B.Divya[2] & B.Preethi[3]
[*1]Assistant Professor, ECE Dept, Vidya Jyothi Institute of Technology, Aziz Nagar, C.B. Post, INDIA
[2&3]B.TECH-Final Year Student, ECE Dept, Vidya Jyothi Institute of Technology, Aziz Nagar, C.B. Post, INDIA

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ABSTRACT
Ultra low power with biomedical frequency low-pass filters has many applications in biomedical signal processing unit. Biomedical signals are usually in the 10mHz to 100Hz frequency range and hence require sub hertz frequency filters to condition to the signal before processing the performance of passive filters degrades at the high frequencies and the required values of resistance and inductance and very difficult to meet from the market. To find a solution to this problem is to study active filters using Operational Transconductance Amplifier (OTA). The aim of this work to determine the values of design parameters that optimize an objective feature where as satisfying specifications or constraints. This fourth order filter is implemented in a 0.18µm technology in terms of power consumption and cutoff frequency this filter performs better than previous filter from the literature. This circuit is used with low frequency signal low power portable medical equipment

KEYWORDS: Biomedical ,OTA, Low Frequency Signal, Power Consumption..

I. INTRODUCTION
The trend in the use of low-voltage power supplies for CMOS integrated circuits is by the reliability issue of small size MOSFET transistors and the increasing use of low-weight long life battery-operated portable electronic system. With rapid development of micro-electrons in the recent past years, more and more applications require an ultra-low amplitude signal measurement module, such as implantable devices in biomedical applications to monitor several Neuromuscular activities. Monitoring biomedical signals of human body is a very interesting topic since it can be used to know the vital health information of the body from the acquired data. These data capacitates medical practitioners to diagnose diseases.

Biomedical signals Electro cardiogram (ECG), Electromyogram (EMG), Electro encephalogram (EEG), are characterized by their low voltage-levels and low frequency. The famous architecture used in biomedical monitoring systems, are an operational amplifiers, must exhibit very low-referred noise ,low power and high Common Mode Rejection Ratio(CMRR). A low voltage, low noise and high CMRR operational amplifier for portable monitoring system is proposed. The operational amplifier is able to work under 1-V supply and has high CMRR.

A normal ECG signal falls in the range of 5u to 8mv. The amplifier is required to increase this weak signal into an acceptable level. The two stage amplifier with miller compensation capacitor (Cc) and nulling active restior(Rz), is used for the design of Op-amp with first stage being a differential input pair and the second, a gain stage. Because the bio-medical signal is so weak, the noise will affect the real bio-medical signal. Due to the low frequency of bio-medical signal the flicker noise dominates, it has strong dependence on the width and length product of a CMOS transistor. The spectral density of flicker noise is inversely proportional to the transistor area W/L. In other words, 1/f noise can have a lesser effect on larger devices. The second stage of op-amp includes an n-channel common source amplifier with a p-channel current source load. The sizes of the transistors were designed for a bias current of 0.5uA to provide for sufficient output voltage swing, output offset voltage, slew rate and gain bandwidth product.

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II. LITERATURE SURVEY

The application is a tiny integrated circuit that is mounted under the patient's skin and monitors cardiac data like ECG. The measurement takes place all over the time, 24/7 and the acquainted data is sent to a central processing unit (e.g. a computer) via radio waves where it is stored and processed. The ECG recordings made by the circuit have very low frequency components that must be separated from the noise that suppresses the useful signal.

Low-frequency filters are important building blocks for biomedical systems, wherein analog pre-processing blocks, such as low noise pre-amplifiers and filters for the acquisition of bioelectric signals are employed. These circuits should not introduce any form of distortion that can destroy the information contained. For this reason, the analog pre-processing blocks must present high performance over the frequency of interest.

The tolerance scheme specifies the pass-band and stop-band bandwidths of the filter and the acceptable ripple in these bands. Because a very steep cut-off filter is needed, filters of higher orders must be examined. The higher the filter order the steeper the cut-off slope is, but proportional to the order it results in a more complex circuit. This trade-off must be kept in view. In this circuit, power consumption is a critical factor thus the complexity of the filter and the steepness must be kept at an optimal value. The filters employed in biomedical systems are used for sensing bioelectrical signals which, typically, are in the range of 1 V–100 mV while the frequencies are below 100 Hz. At the input, a low-pass filter (LPF) is usually employed in order to limit the frequency band. The design of very low-frequency filters (10 Hz) is not straightforward, especially for integrated circuit implementation.

However, despite their utility, creating large time constant low-pass filters on-chip is a challenging problem. To implement large time constants, switched-capacitor-based topologies require large capacitor ratio sand a sufficiently high power supply must be used to achieve an acceptably low switch ON-resistance.Switched-capacitor filter has been successfully applied to many voice band applications.

It has good accuracy of time constants and good temperature characteristics; whereas the problem of clock feed-through is difficult to be solved and it also needs continuous-time filtersas anti-aliasing filters. Another alternative is to use Gm-C filters which do not have the aliasing problem of sampled-data systems. Due to the dependence of the cut-off frequency of the filter on the absolute values of monolithic components such as capacitors and transistor transconductances, which are both process and temperature dependent, feedback and cancellation techniques are required to control the cut-off frequency of this type of filters. And it also needs a small trans conductance in order to avoid using large area capacitors at low frequency. This work describes a low cut-off frequency CMOS low pass filter which utilizes a cross-coupled input structure to cancel the deviation of the cut-off frequency under the influence of different temperature and produce an appropriate trans conductance with four auxiliary amplifiers to keep the gain. It is a monolithic filter with low power consumption and low-voltage.

CMOS amplifiers and its different architectures:
The performance of filters designed by the use of passive components degrades at audio frequencies and the required resistances and inductances values calculated from the mathematical expression are very difficult to meet from the market. To find a solution to this problem this paper presents a study to realize Passive Filters into Active Filters using Operational Amplifier. Basic properties of Operational amplifiers are also discussed. By controlling the Voltage Gain of op-amp, one can change its constraints, which is very useful in the designing the first order and second order active filters. In this article only first order low pass filters using Op-amp is designed. It is concluded that the new approach gives us a wide range of tunable cut-off frequencies filters.

III. FILTERS

An electrical filter is a circuit that can be designed to modify, reshape or reject all unwanted frequencies of an electrical signal and accept or pass only those signals wanted by the circuits designer. In other words they "filter-out" unwanted signals and an ideal filter will separate and pass sinusoidal input signals based upon their frequency. Filters are networks that process signals in a frequency-dependent manner. The basic concept of a filter can be explained by examining the frequency dependent nature of the impedance of capacitors and inductors. Consider a voltage divider where the shunt leg is reactive impedance. As the frequency is changed, the value of the reactive impedance changes as a result voltage divider ratio changes. This mechanism yields the frequency dependent change in the input/output transfer function that is defined as the frequency response.

Filters have many practical applications. A simple, single pole, low-pass filter (the integrator) is often used to stabilize amplifiers by rolling off the gain at higher frequencies where excessive phase shift may cause oscillations. A simple, single pole, high pass filter can be used to block DC offset in high gain amplifiers or single supply circuits. Filters can be used to separate signals, passing those of interest, and attenuating the unwanted frequencies.

There are a large number of texts dedicated to filter theory. No attempt will be made to go heavily into much of the underlying math: Laplace transforms, complex conjugate poles and the like, although they will be mentioned. While they are appropriate for describing the effects of filters and examining stability, in most cases examination of the function in the frequency domain is more illuminating.

An ideal filter will have an amplitude response that is unity (or at a fixed gain) for the frequencies of interest (called the pass band) and zero everywhere else (called the stop-band).The frequency at which the response changes from pass-band to stop-band is referred to as the cut-off frequency.3.1 Types of filter
Filters can be divided into two distinct types.

1) Based on Component used:

Based on the component used, filters can be divided into two types

- **A. Active filters**
- **B. Passive filters.**

Active Filters
It contains amplifying devices to increase signal strength while passive do not contain amplifying devices to strengthen the signal. As there are two passive components within a passive filter design the output signal has smaller amplitude than its corresponding input signal, therefore passive RC filters attenuate the signal and have a gain of less than one, (unity).

A Low Pass Filter can be a combination of capacitance; inductance or resistance intended to produce high attenuation above a specified frequency and little or no attenuation below that frequency. The frequency at which the transition occurs is called the "cut-off" frequency. The simplest low pass filters consist of a resistor and capacitor but more sophisticated low pass filters have a combination of series inductors and parallel capacitors.

In low frequency applications (up to 100kHz), passive filters are usually made from simple RC (Resistor-Capacitor) networks while higher frequency filters (above 100kHz) are usually made from RLC (Resistor-Inductor-Capacitor) components. Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.

Passive Filters
Passive implementations of linear filters are based on combinations of resistors (R), inductors (L) and capacitors (C). These types are collectively known as passive filters, because they do not depend upon an external power supply and/or they do not contain active components such as transistors.

Inductors block high-frequency signals and conduct low-frequency signals, while capacitors do the reverse. A filter in which the signal passes through an inductor, or in which a capacitor provides a path to ground, presents less attenuation to low-frequency signals than high-frequency signals and is therefore a low-pass filter. If the signal passes through a capacitor, or has a path to ground through an inductor, then the filter presents less attenuation to high-frequency signals than low-frequency signals and therefore is a high-pass filter. Resistors on their own have no frequency-selective properties, but are added to inductors and capacitors to determine the time-constants of the circuit, and therefore the frequencies to which it responds.

2) Based on frequency of signals they allow to pass through them

Based on frequency of signals they allow to pass through them, filters can be divided into following categories:

Low Pass Filter

There are Low-pass filters that allow only low frequency signals to pass, where fc is cut off frequency.

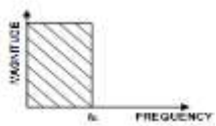

Fig 3.1 Low pass Filter characteristic

An ideal low-pass filter completely eliminates all frequencies above the cut-off frequency while passing those below unchanged; its frequency response is a rectangular function. The transition region present in practical filters does not exist in an ideal filter. An ideal low-pass filter can be realized mathematically (theoretically) by multiplying a signal by the rectangular function in the frequency domain or, equivalently, convolution with its impulse response, a sinc function, in the time domain.

However, the ideal filter is impossible to realize without also having signals of infinite extent in time, and so generally needs to be approximated for real ongoing signals, because the sinc function's support region extends to all past and future times. The filter would therefore need to have infinite delay, or knowledge of the infinite future and past, in order to perform the convolution. It is effectively realizable for pre-recorded digital signals by assuming extensions of zero into the past and future, or more typically by making the signal repetitive and using Fourier analysis.

High-Pass Filters

High-pass filters that allow only high frequency signals to pass through.

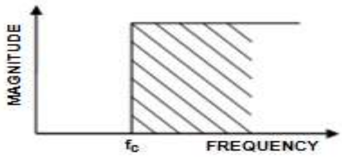

Fig 3.2 High pass filter characteristic

Band-Pass Filters

Band pass filter that allow signals falling within a certain frequency range to pass through. If a high-pass filter and a low-pass filter are cascaded, a band-pass filter is created. The band-pass filter passes a band of frequencies between a lower cut-off frequency, f l, and an upper cut-off frequency, f h. Frequencies below f l and above f h are in the stop-band.

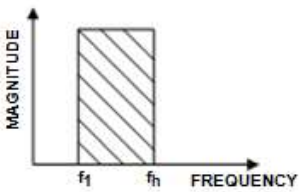

Fig 3.3 Band pass filter characteristic

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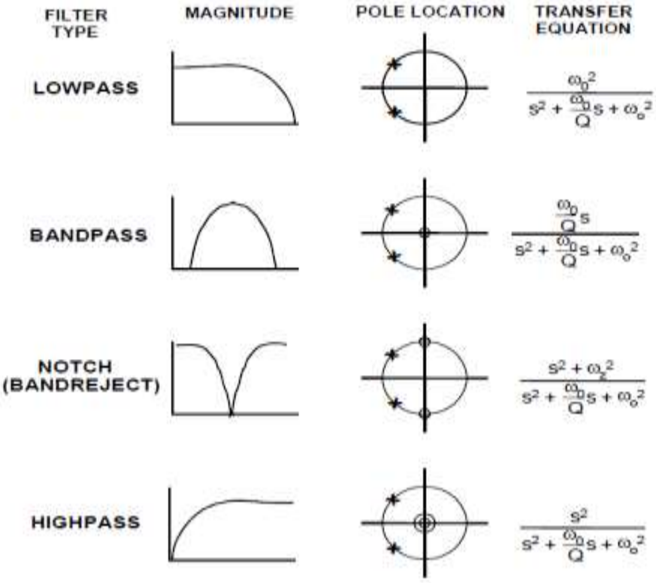

Fig 3.4: Standard second order filter response

IV. CMOS

Complementary metal–oxide–semiconductor (CMOS) is a technology for constructing integrated circuits. CMOS technology is used in microprocessors, microcontrollers, static RAM, and other digital logic circuits. CMOS technology is also used for several analog circuits such as image sensors (CMOS sensor), data converters, and highly integrated transceivers for many types of communication. Frank Wanlass patented CMOS in 1963 (US patent 3,356,858).

CMOS is also sometimes referred to as complementary-symmetry metal–oxide–semiconductor (or COS-MOS). The words "complementary-symmetry" refer to the fact that the typical design style with CMOS uses complementary and symmetrical pairs of p-type and n-typemetal oxide semiconductor field effect transistors (MOSFETs) for logic functions.

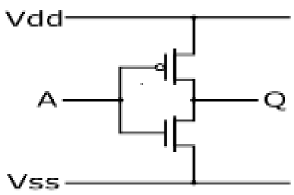

Fig 4.1 CMOS INVERTER

Two important characteristics of CMOS devices are high noise immunity and low static power consumption. Since one transistor of the pair is always off, the series combination draws significant power only momentarily during switching between on and off states. Consequently, CMOS devices do not produce as much waste heat as other forms of logic, for example transistor–transistor logic (TTL) or NMOS logic, which normally have some standing current even when not changing state. CMOS also allows a high density of logic functions on a chip.

It was primarily for this reason that CMOS became the most used technology to be implemented in VLSI chips.The phrase "metal–oxide–semiconductor" is a reference to the physical structure of certain field-effect transistors, having a metal gate electrode placed on top of an oxide insulator, which in turn is on top of a semiconductor material. Aluminium was once used but now the material is polysilicon. Other metal gates have made a comeback with the advent of high-k dielectric materials in the CMOS process, as announced by IBM and Intel for the 45 nanometer node and beyond.

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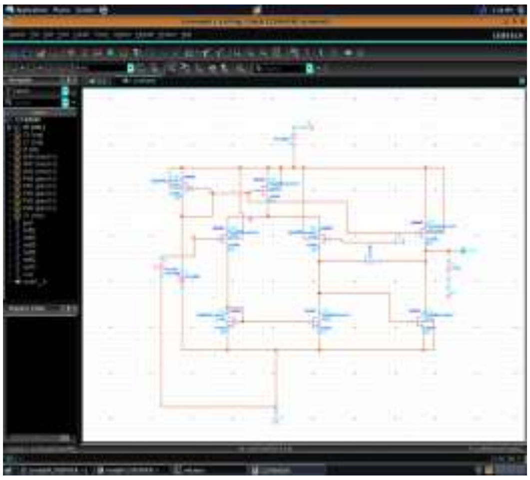
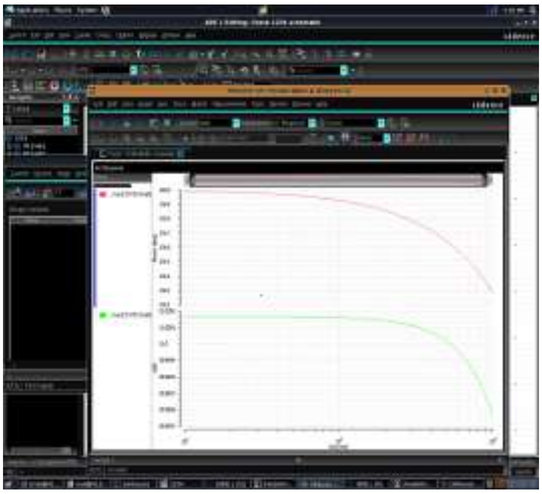
V. RESULTS

Schematic of Operational Amplifier with CMOS



Output gain response



In this,we have got Gain as 25db only, which is less.So ,to increase the gain we have replaced normal MOSFET's with DTMOS. We need to calculate W/L ratio for each DTMOS like above procedure. In that way we have achieved below values

Table 1: W/L ratios of DTMOS

Device	**Type**	**W(um)**	**L(um)**
M1&M2	**P**	**5**	**0.380**
M3&M4	**N**	**45**	**0.480**
M5&M8	**P**	**18**	**0.555**
M7	**P**	**10**	**0.380**
M6	**N**	**25**	**0.100**

After calculating these parameters we have designed a LOW PASS FILTER with cut-off frequency of 100 Hz.

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Low pass filter design results

To design a LOW PASS FILTER, we require R and C values. The frequency depends on these parameters by the formula of

$$f = 1 / 2 * \pi * R * C$$

We need to design a LPF which will be used for bio-medical applications. So, LPF should have a less cut-off frequency. For this we should calculate R & C values which should satisfy required frequency.We have kept **1**00Hz as a cut-off frequency, and calculated R & C values using above formula. In that way we have,

F = 100Hz, R = 10ohms, C = 890pf

With these values we have implemented LOW PASS FILTER USING OPERATIONAL AMPLIFIER using above values and simulated

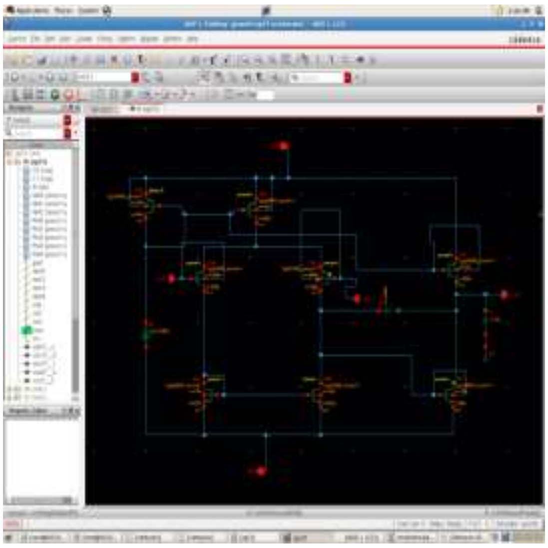

Fig 4.3 Operatinal Amplifier using DTMOS

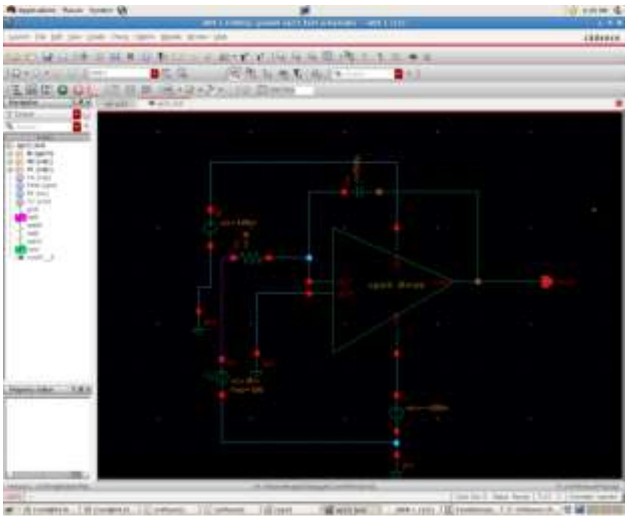

Fig4.4 LPF using OP-AMP

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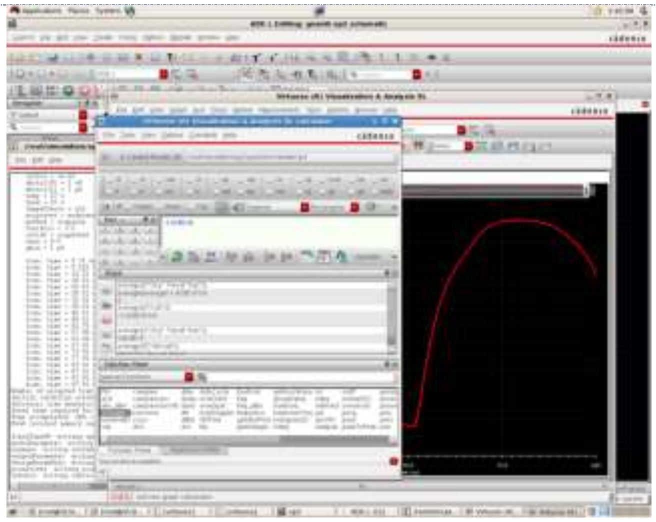


Fig 4.5 Current in the circuit

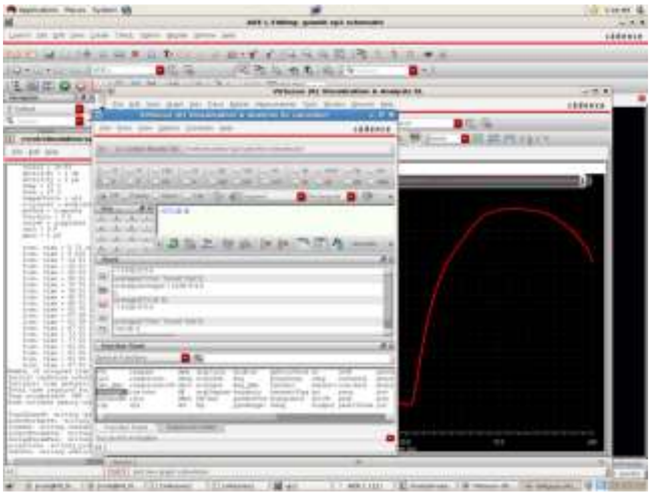
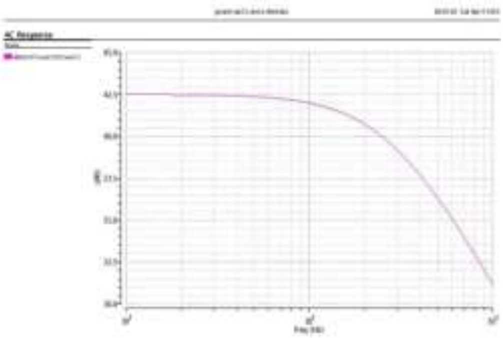


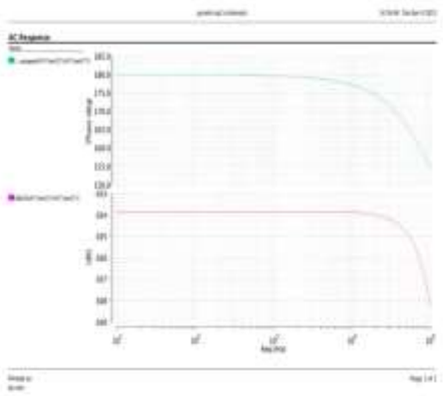
Fig 4.6 Power dissipation

Gain response

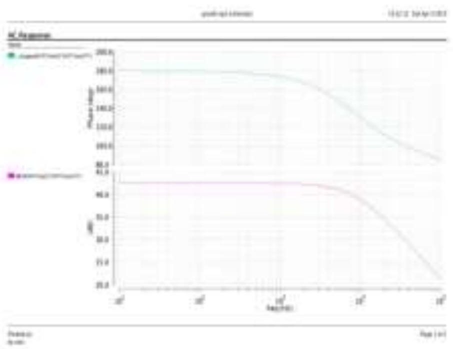


Gain of LPF is **42.5db**
Cut-off frequency is **100**

Common Mode Response



Differential Mode Response



VI. CONCLUSION AND FUTURE SCOPE

Conclusion

We present a Active CMOS LPF using Two-stage operational amplifier topology for low voltage and low power, ECG Monitoring System applications, This two-stage amplifier with Miller compensation can be used in low power, low voltage High CMRR and PSRR applications such Biomedical instrument and a small battery operated devices. The circuit has been designed in a SPECTRE using 0.90um CMOS technology. To reduce the noise of the amplifier, we used the P-channel input devices with N-channel load, because it's flicker noise is less than that the N-channel input devices with P-channel load.

We have described an ECG amplifier with low input-referred noise, 146-dB CMRR, less than 600nW of power consumption, and good cardiac signal fidelity. Proposed two-stage operational amplifier with Miller compensation (Cc), is well suited to biomedical systems such as cardiac pacemaker, electrocardiogram (ECG) where low-power consumption is of primary concern. It seems that the input-referred-noise not minimized well, we can reduce flicker noise by using techniques, such as auto-zero-technique,or chopper-stabilization technique.

Future Scope

This work can be extended to designing of low pass filter with low frequency and low power in the future. However, the basic need in order to design low pass filter for low power is to minimize the power of OTA. The proposed clocked transconductor topology is thus highly suitable for use in low power, low-voltage sensor interfaces and in portable medical instrumentation. This can further be used for lower cut-off frequency and power. And since it is 1st order filter so for improved performances higher order filters for few nw power can be designed using this topology

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