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An Overview on Low Voltage Low Power Operational Transconductance Amplifier (OTA) for Biomedical Application

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ABSTRACT:
The operational transconductance amplifier (OTA) is a widely used analog processing block. In recent years, the development of OTA with very low conductivity, low power, low voltage and improved linearity has been mainly used in biomedical applications. In this paper explores the relationship between power consumption and the linearity of CMOS OTA behavior for low frequency or biomedical applications, which are presented in various literature sources. Comparison among the OTA are done in terms their linearity, technology, supply voltage, power consumption, frequency and their application in biomedical signal processing. This document will help future researchers to better develop OTA in terms of linearity, low energy consumption, and low frequency or biomedical applications.
Keywords: CMOS, Operational Transconductance Amplifier (OTA), Biomedical Signal, Low Frequency, power consumption, EEG, ERG, ECG, VC.

I. INTRODUCTION

The world of biomedical electronics is developing rapidly with new projects and new technologies. Currently biomedical devices are manufactured with a large number of functions, accuracy, accuracy, compactness and ease of use. In portable biomedical devices, power consumption has become a serious problem due to battery life. Portable biomedical device designs should provide a lower noise response depending on the characteristics of biomedical signals. Due to the rapid and numerous development of microelectronics in recent years, more and more applications require a very small amplitude signal measuring module, for example, implantable devices in biomedical applications. Monitoring various biomedical signals of the human body is a very interesting topic, because it helps to reveal important information about human health from the collected data. Doctors use this data to diagnose diseases. Biomedical signals such as electrocardiogram (ECG), electromyogram (EMG), electroencephalogram (EEG) [1].

Biomedical applications such as ECG and EEG require very power efficient designs, since portable biomedical sensors are usually battery powered. ECG and EEG are two of the most important part in biomedical system. These biomedical applications are used to control the function of the two main parts of the human heart and brain.

To obtain the activity of the heart and brain, analog processing cells are needed. These cells connect to the skin via an electrode to record the activity of the heart and brain. Various ICs have been developed for direct activity recording. In these chips, the low pass filter is the most important part. The cut-off frequency in the low-pass filter in the ECG and EEG is 250 Hz or 200 Hz [2]. Filter implementations have many methods, such as Gm-c, Active RC, OTA-C, and a switched capacitor. Filter selection can be made according to frequency requirements.

The implementation of the low-frequency design is not easy to design, since the Gm value requirement is in the nA / V range, and the capacitor value is greater than 100pF. Many foundries cannot provide a capacitor value of more than 50 pF, also due to the large area of a large-scale condenser, which cannot be easily realized. Another problem with low nA / V steepness is worsened by noise, distortion, and imperfection [3].

II. LITERATURE REVIEW

Moulahcene Presented a two-stage amplifier topology for ECG low voltage and low power ECG control applications. This two-phase amplifier can be used with Miller compensation in low voltage and low voltage (CMRR) and PSRR applications such as biomedical devices and small battery devices [4].

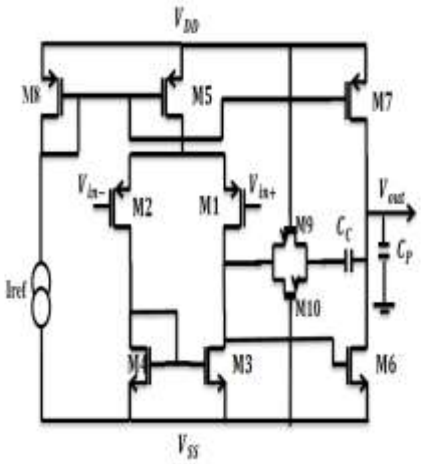

Figure 1 : Schematic of Two-stage Operational Amplifier [4]

The circuit is designed in SPECTRUM using 0.90um CMOS technology. To reduce amplifier noise, we use P-channel input devices with an N-channel load, because the flash noise is less than the noise of N-channel input devices with a P-channel load. We have described the ECG amplifier with calculated low noise, CMRR 131 dB, and less than 3uW of energy consumption and good sincerity for heart health.

Laoue et. al. presented a design of an ultra-low power telescopic OTA using the bulk-driven technique. In this work proposed design was implemented using the CMOS 180nm technology with ±0.5V supply voltage and achieved bandwidth is 250Hz with power consumption of 386nW [5]. Gracia et. al. presented a novel low power and low noise OTA design which is used in cardiac implantable medical devices for monitoring of the heart activities. In this proposed design 45nm CMOS technology was used and measures the gain 51dB with power supply of 1V and the power consumption of the proposed OTA was got 11.9µW [6]. Rodrigues et. al. presented low power and very low tansconductance OTA design for biomedical application. the proposed OTA design based on the series parallel gate driven technique and implement it using cadence software with 180nm CMOS technology. In this proposed design implement 1.6V supply voltage is used with 24.63nS transconductance and 194.33nW power consumption [7].

Telnaz Zarifi explained that because of the interest in personal medical monitoring in real time, the demand for more complex and efficient medical equipment is growing at home. Electroencephalogram (EEG) is a non-invasive method that is common to various applications, such as predicting epileptic seizures and computer-brain interface (BCI). An important element of the EEG monitoring system is a circuit with very low energy consumption. This article describes the implementation of an EEG signal amplifier. This amplifier is designed and modeled using CMOS technology 90 nm 1 P 9 M, simulates, consumes 3.6 µW of 1.2 V supply voltage and occupies an active area of 0.048 mm 2. The bandwidth increases with low-frequency cutoff less than 0.1 Hz at high frequency off 10 kHz, adapted to the EEG signal. The amps are modeled using the actual EEG signal recorded using the EEG-1100 from Emama Res. Proposed the low-power, low-power amplifier shown below is suitable for small portable EEG control systems. This amplifier is designed and modeled using CMOS 1 P 9 M 90 nm technology, which consumes 3.6 mW at a supply voltage of 1.2 V [8].

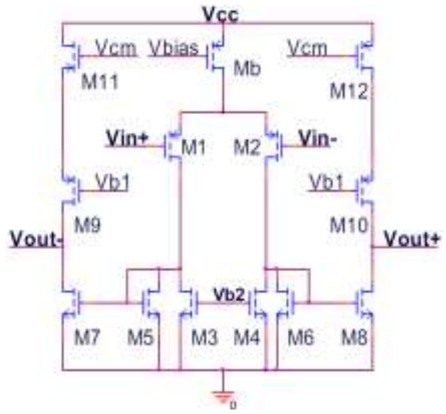

Figure 2 : High swing current mode OTA [8]

Soni et. al. present a novel OTA design for biomedical or low frequency application using CMOS 90nm technology. In proposed design achieved the 250Hz frequency for ECG application. The design implemented using CMOS 90nm technology, ±0.35V power supply and achieved the power consumption of proposed design 5.98nW [9].

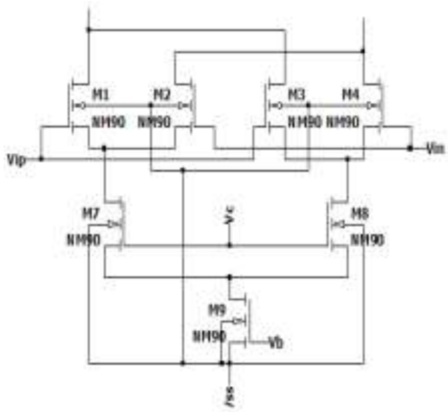

Figure 3 : Schematic of OTA design Using Multi tanh Linearization Technique [9]

Raha [10], introduced the previous technology, expands the digital circuit to operate at low voltage and reduces energy consumption. All physical signals are analog in nature, so we need an analog interface module, like the front end. In the proposed design implementation, the mass-driven operational transconductance amplifier with local common mode feedback, which shows OTA design to realize LPF filter with cut off frequency of 250 Hz is implemented with very low consumption and low frequency. In order to further reduce the cut off frequency, a capacitance multiplier is used.

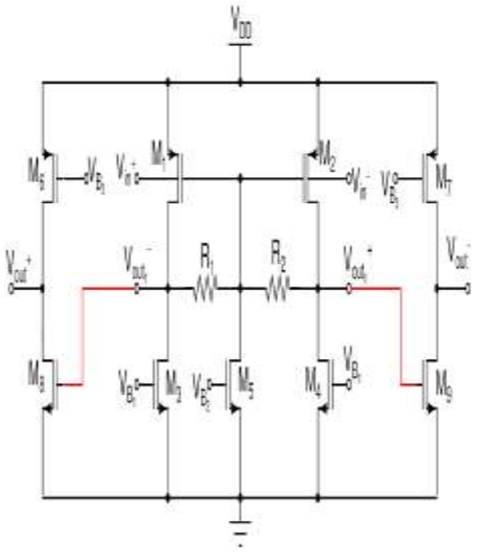

Figure 4 : Two stage Bulk driven OTA [10]

There are many greetings to the problem of large capacitors, and in the previous literature a very low slope is given. In [11], a 2.4 Hz low-pass filter achieves a dynamic range of 60 dB with a linear conductivity of 2nA / V and a capacitor 5A and OTA. In [11] dynamic range of the filter was 60dB which is very high and it is achieve by keeping the $V_{DSAT} > 2V_{DMAX}$,where V_{DSAT} is the saturation voltage of the input transistor and V_{DMAX} is the maximum differential input voltage. To avoid system noise, the current splitting technique is applied. The OTA scheme used in [4] is shown in the figure below.

The OTA slope in [11] is given by

$$G_m = \frac{i_o}{v_1 - v_2} = \frac{N-1}{M+N+1} g_{oMR} \quad \text{\_\_\_\_(1)}$$

Where g_{oMR} is small signal source to drain conductance of transistor M R, given by

$$g_{oMR} = \mu_p C_{ox} \frac{W_{MR}}{L_{MR}} (V_{SDMR} - V_T) \text{\_\_\_\_ (2)}$$

The value of M (in Equation 1) is defined as the slope coefficient between MM and M1, and N is the value of the slope coefficient between MN and N1.

In OTA-C filters frequency is given by

$$f_o = \frac{G_m}{2\pi C_L} \quad \text{\_\_\_\_\_\_\_\_ (3)}$$

The filter constructed by this G_m circuit is 6th order 2.4Hz low pass filter with ±1.5V power supply and power consumption below 10µW and area is $1mm^2$

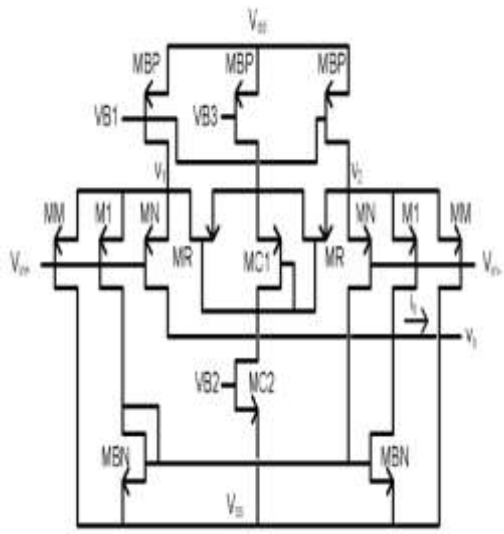

Figure 5: Single ended OTA for low frequency operation [11]

III. BIOMEDICAL SIGNAL PROCESSING SYSTEM

The most important part of the biomedical system is the analog processing unit, in which the Bock includes a preamp and filter. The most common filter used to process biomedical signals is OTA as the base module, since the biomedical signal system operates at a very low frequency.

The preamplifier should amplify the input signal to a higher level with low noise and low distortion. For example, in applications for an electrocardiograph, where the magnitude of the signals of a preamplifier should be processed to 100 mill volts using a low-pass filter. High performance very low-pass filter can be effectively implemented in CMOS technology [2].

TABLE I: Most Commonly Used Biomedical Signals

Signal	Frequency
ECG	250Hz
EEG	200Hz
ERG	100Hz

Electroencephalograph (EEG) is known as electrical recording of brain activity. It has many diagnostic and research applications for brain research. The electroencephalograph can be recorded from the human brain by placing electrodes on the surface of the head, but the received signal is very small (on the order of several micro volts) to be recorded or digitized (for example, an analog-to-digital converter). [15].

TABLE II: Comparison of the performance of different low voltage low power OTA

Ref. No.	[4] 2020	[5] 2019	[6] 2019	[10] 2017	[12] 2017	[13] 2016	[14] 2014
CMOS Process	0.18 µm	45nm	0.18 µm	0.18 µm	0.13 µm	0.18 µm	90 nm
Application	ECG	ECG	EEG	ECG	EEG	EEG	ECG
Power Consumption	380 nW	11.9µW	194.3 nW	15 nW	216 nW	2.2 µW	2.6 µW
Supply Voltage	±0.5V	1V	1.6V	0.5V	0.4V	1V	1V

IV. CONCLUSION

The design of a low-power low-frequency operational converter (OTA) required very small values of slope and very high values of the capacitor, but a capacitance value exceeding 100 pF in CMOS technology was not required. easy and inexpensive to manufacture. Therefore, in order to maintain the value of the capacitor, it is low. a literature study showed various methods for keeping the slope and magnitude of the capacitor low. Among all the methods described above, one of them is mixed with others to increase the effectiveness of the proposed design.

The frequency indicated in the previous working paper can be used to optimize the low-voltage low-power CMOS OTA design. This OTA, which should be developed, is used for biomedical applications, such as ECG, EEG, ERG, EMG, etc.

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