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A Review on Low Voltage Low Power Operational Transconductance Amplifier (OTA) for Biomedical Application

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Abstract

A novel differential input signal output operational transconductance amplifier is presented in this paper. The topology proposed consists of an input stage based on a folded cascaded amplifier, and an output stage based on a current source amplifier and a bulk-driven current mirror. The simulations show that the amplifier has a 1.94w power dissipation.. 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, electrocardiograph (ECG), electroencephalograph (EEG).

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) [3].

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 [1]. 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.

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 [5].

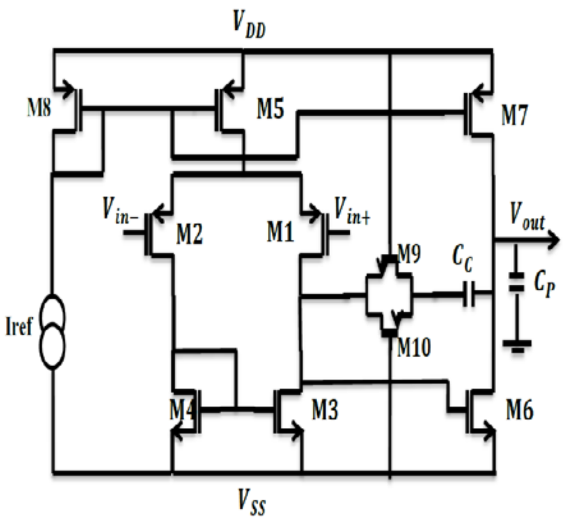

Figure 1 : Schematic of Two-stage Operational Amplifier [5]

The circuit at SPECTRUM was designed using CMOS 0.90um technology. To reduce the noise of the amplifier, we use P-channel input devices with N channel load, because the flash noise is less than the noise of the N-channel input devices with P channel loading. Good for heart health.

Hyung integrated amplifier low feedback amplifier circuit provided SOC neurons in medical implants using 0.18 ورنm CMOS technique. The proposed neural amplifier achieves a voltage gain of 40 dB and built-in noise of 4.3 µVrms in a range from 1 Hz to 10 kHz based on the OTA unit based on a direct decoder and a current of 2.2 µA in cascade degradation with the supply voltage of 1 V. Integrated amplifier amplifier achieves a noise efficiency factor of 3.07 and occupies an area of 0.136 mm2 [1].

Telanaz Zarifi explained that due to the interest in personal medical monitoring in real time, the demand for more sophisticated and effective medical equipment is increasing at home. EEG is a non-invasive method common in many applications, such as prediction of epileptic seizures and a brain computer interface (BCI). An important component of the EEG monitoring system is the circuit with very low power consumption. This article describes the implementation of the EEG signal amplifier. This amplifier is designed and modeled using 90 nm 1 P 9 M CMOS technology, 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 10 kHz High frequency, suitable for EEG signal. Amp is modeled using the actual

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EEG signal recorded using Emma Res EEG-1100. The low and low power amplifier shown below is suitable for small portable EEG control systems. The amplifier is modeled and modeled using CMOS 1 P 9 M 90 nm technology, which consumes 3.6 MW at a supply voltage of 1.2 V [9].

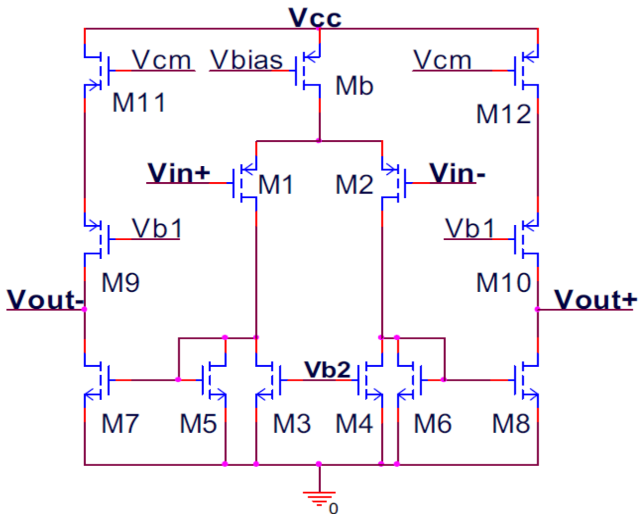

Figure 2 : High swing current mode OTA [9]

Edwin explained that the demand for medical surveillance products is growing worldwide. Low-power and low-voltage attributes are important issues that need to be addressed in the circuit. It is used for personal health monitoring and prolongs battery life. In this article, Edwin introduced a biomedical amplifier designed to detect electrocardiogram (ECG) signals. The design includes a high pass filter (HPF), a calculation filter. It consists of a resistance amplifier (OTA), two linear amplifiers with variable gain, three low-pass filters (LPF) and an operational transistor amplifier (ORA). In particular, VGA and LPF use log compression technology. [8].

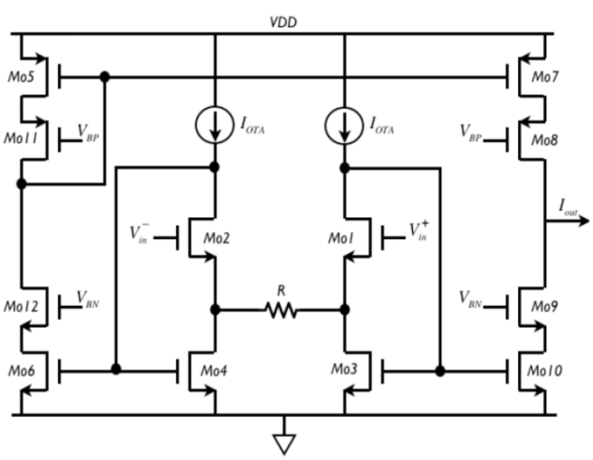

Figure 3 : Schematic of OTA source degeneration structure [8]

Chinmayee introduced a new circuit topology for low voltage, low noise (AI) device amplifiers that applies to EKG signal acquisition systems. This circuit relies on the current feedback topology that is performed using successive structures folded at the input and output stages. This makes it possible to discover a very low common voltage [10].

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Raha [2], introducing the previous technology, expanded the digital circuit to operate at low voltage and reduce energy consumption. All physical signs are representative in nature, so we need a representative interface unit, like the front end. In carrying out the proposed design, much-driven operational conductive amplifier with domestic common mode feedback is implemented, which indicates OTA design to achieve LPF filter with cut-off frequency of 250 Hz, with very low consumption and low frequency. In order to further reduce the cutoff frequency, the amplitude multiplier is used.

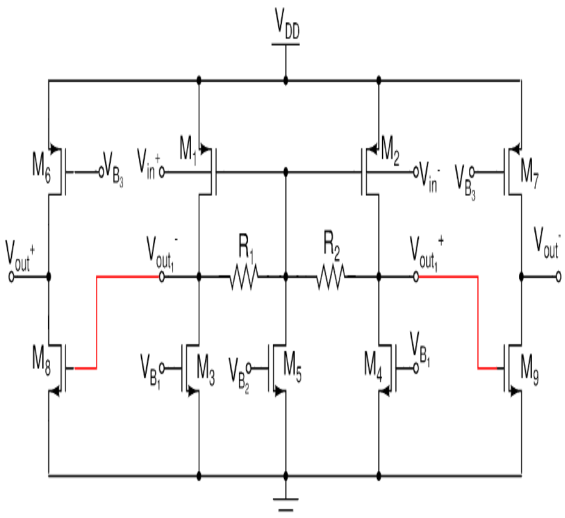

Figure 4 : Two stage Bulk driven OTA [2]

OTA (Operational Transconductance Amplifier) OTA are used to implement low-power OTA low-power topologies. OTA are input and output voltage amplifiers. The slope gm is proportional to the iDS drain current and increases the efficiency of the amplifier current [6].

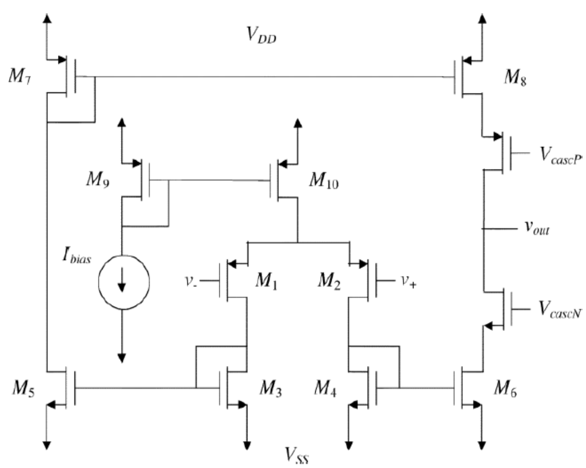

Figure 5 : Current mirror OTA for Neural amplifier [6]

Lipika provided that the LNA amplifier is the first gain stage for each receiver. It focuses heavily on the design of high frequency LNA applications and is very popular for low frequency designs. Neurons communicate with each other, generating a nerve signal that can be used to analyze brain activity. Close monitoring includes these signals supported by modern IC technology, allowing people in the lock state to use various prostheses effectively. The most common non-invasive way to record neural activity is to use a non-localized electrode on the scalp which is the EEG recording [14].

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There are many regards to the problem of large capacitors, and in the previous literature a very slight slope is given. In [4], a 2.4 Hz low-pass filter reaches a dynamic range of 60 dB with a 2nA / V linear connection, a 5A capacitor and an OTA. In [4] the dynamic range of the filter was 60 dB, which is extremely high and is obtained by maintaining VDSAT> 2VDMAX, where VDSAT is the saturation voltage of the input transistor and VDMAX is the input voltage maximum difference. To avoid system noise, current splitting technology is applied. The OTA chart used in [4] is shown in the figure below.

The OTA slope in [4] 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

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

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 6^{th} order 2.4Hz low pass filter with ±1.5V power supply and power consumption below 10µW and area is $1mm^2$

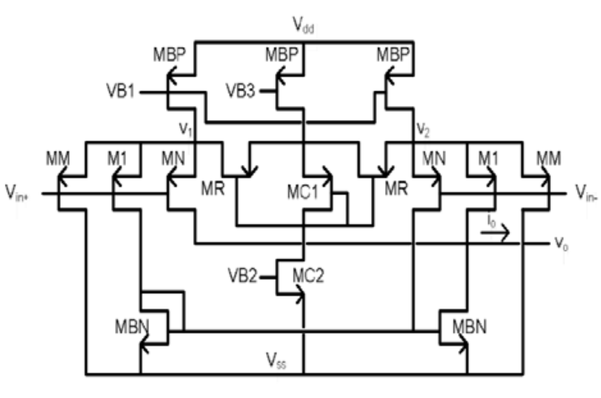

Figure 6: Single ended OTA for low frequency operation [4, 12]

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.

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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 [4].

Table 1: 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). [2].

Table 2: Comparison of the performance of different low voltage low power OTA

Ref. No.	[5] 2014	[7] 2013	[2] 2017	[14] 2018	[13] 2017	[1] 2016	[8] 2007	[9] 2011
CMOS Process	90 nm	0.18 µm	0.18 µm	0.18 µm	0.13 µm	0.18 µm	0.18 µm	90 nm
Application	ECG	ECG	ECG	EEG	EEG	EEG	ECG	EEG
Power Consumption	2.6 µW	7.243 µW	15 nW	593.5nW	216 nW	2.2 µW	17 µW	3.6 µW
Supply Voltage	1V	1V	0.5V	1.8V	0.4V	1V	1V	1.2V

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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