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

Vinita
M.Tech Student, Department of ECE,
Sobhasaria Group of Institutation, Sikar (Raj), India,

Mukesh Kumar Saini
Assistant Professor, Department of ECE,
Sobhasaria Group of Institutation, Sikar (Raj), India,

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 paper will help for 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).

1. 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.

2. LITERATURE REVIEW

Hyung Presented a low power capacitive feedback amplifier integrated circuit for neural SoC in medical implants using 0.18 μm CMOS technology has been presented. The proposed neural amplifier achieves a 40 dB voltage gain and an integral input noise of 4.3 μVrms in the 1 Hz to 10 kHz range based on an OTA based on a forward decoder and degenerate cascade 2.2 μA current with 1 V supply voltage. The designed amplifier's integrated circuit achieves a noise efficiency factor of 3.07 and occupies an area of 0.136 mm 2 [2].

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 [3].

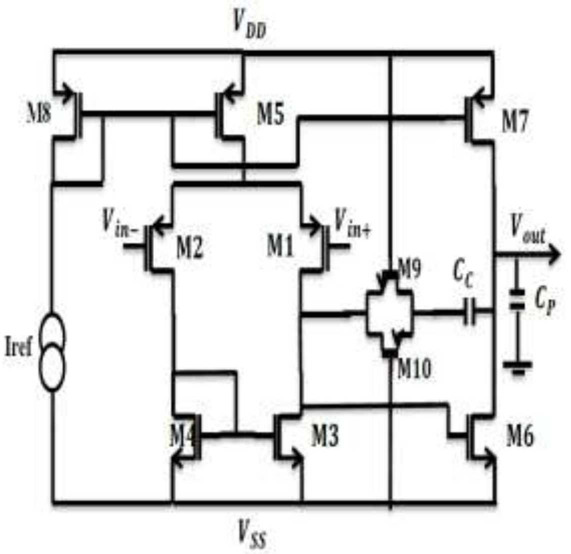

Figure 1 : Schematic of Two-stage Operational Amplifier [3]

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.

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 in figure 2 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 [4].

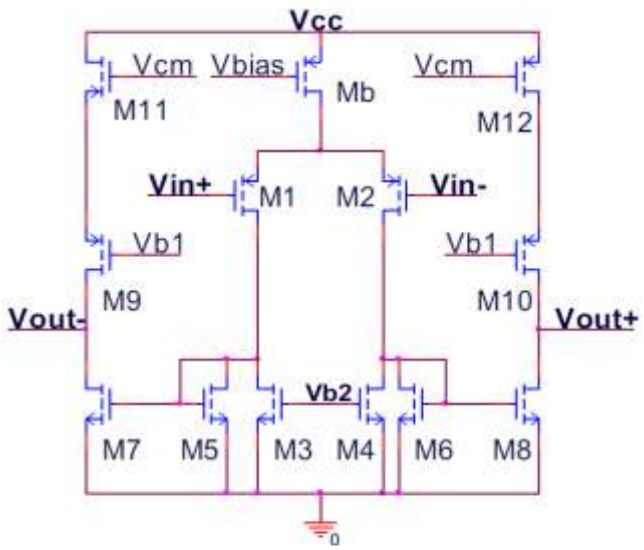

Figure 2 : High swing current mode OTA [4]

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. [5].

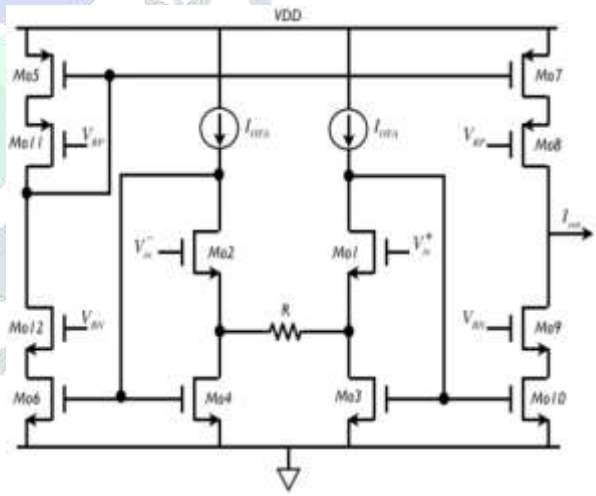

Figure 3 : Schematic of OTA source degeneration structure [5]

Chinmayee Presented a new circuit topology for low voltage, low noise instrumentation amplifiers (IA) applicable to electrocardiogram signal acquisition systems has been designed. This circuit is based on a current feedback topology implemented using cascade structures folded at the input and output stages. This helps to detect very low common mode voltage [6].

Rakhi [7], 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.

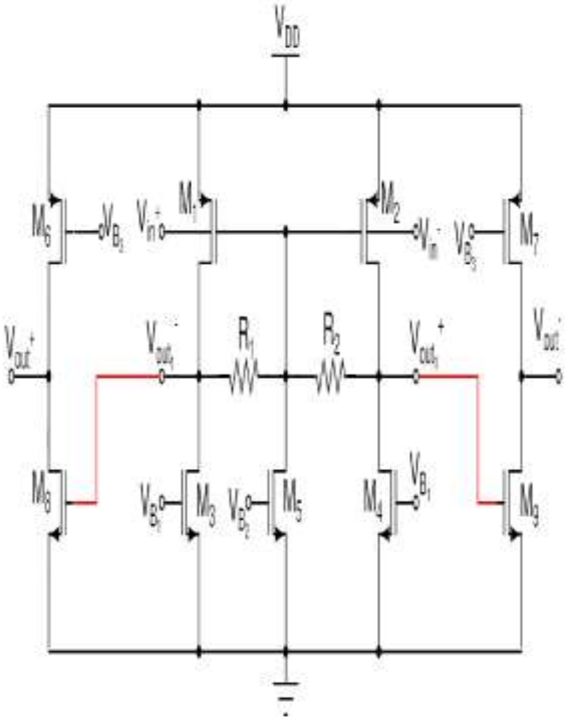

Figure 4 : Two stage Bulk driven OTA [7]

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 [8].

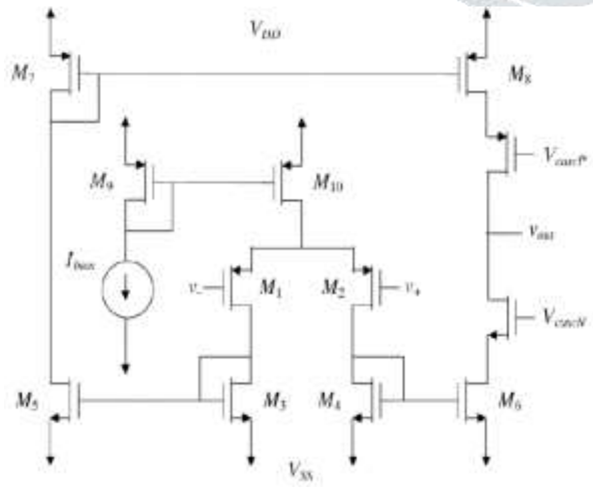

Figure 5 : Current mirror OTA for Neural amplifier [8]

Lipika Presented that A low noise amplifier (LNA) is the first gain stage of every receiver. Enough Focusing on the design of high frequency LNA Applications are also very popular for low frequency designs. Neurons communicate with each other, Generate a neural signal that can be used to analyze the activity of the brain. Include Close monitoring of these signals supported by modern IC technology, Allow people in locked state to effectively use various prostheses. The most commonly used non-invasive method for recording neural activity is to use a non- Placing an electrode on the scalp is a brain wave recording (EEG) [9].

There are many greetings to the problem of large capacitors, and in the previous literature a very low slope is given. In [10], 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 [10] 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 which is shown in the figure below.

The OTA slope in is given by

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

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

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

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

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

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 $1mm^2$

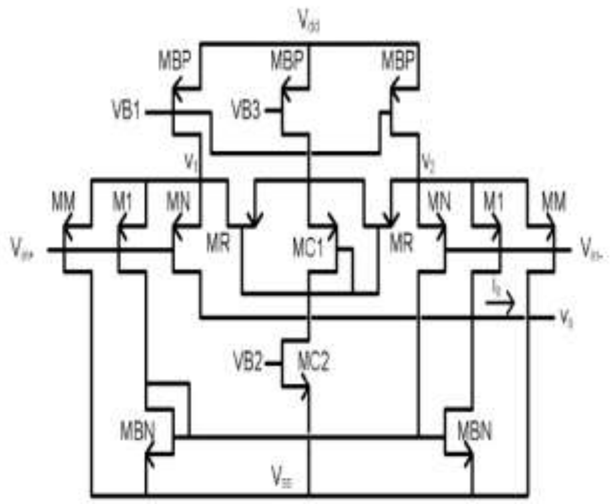

Figure 6: Single ended OTA for low frequency operation [10, 11]

3. 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.

Biomedical signals, such as electrocardiogram (ECG), Electroencephalogram (EEG), Electroretinography (ERG) are characterized by their low voltage-levels and low frequency, Table 1 shows the characteristics of these signals [3].

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). [2]. Electrocardiogram (ECG) signal plays a vital role in the monitoring and diagnosis of the health conditions of the heart [3]. Electroretinography (ERG) is an eye test used to detect abnormal function of the retina (the light-detecting portion of the eye). Specifically, in this test, the light-sensitive cells of the eye, the rods and cones, and their connecting ganglion cells in the retina are examined.

TABLE II: Comparison of the Performance of Different Low Voltage Low Power OTA

Ref. No.	[2] 2016	[3] 2014	[4] 2011	[5] 2007	[6] 2010	[7] 2017	[8] 2013	[9] 2018	[12] 2003	[13] 2017
CMOS Process	0.18 µm	90 nm	90 nm	0.18 µm	0.18 µm	0.18 µm	0.18 µm	0.18 µm	1.5 µm	0.13 µm
Application	EEG	ECG	EEG	ECG	ECG	ECG	ECG	EEG	EEG	EEG
Power Consumption	2.2 µW	2.6 µW	3.6 µW	17 µW	110 µW	15 nW	7.243 µW	593.5nW	0.9 µW	216 nW
Supply Voltage	1V	1V	1.2V	1V	1V	0.5V	1V	1.8V	±2.5V	0.4V

4. 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.

REFERENCES

[1] Rajeev Kumar, Sanjeev Sharma And Amandeep Singh, " A Low Power Low Transconductance Ota In 180nm Cmos Process For Biomedical Applications", IJCTA, Vol-9, Issue- 11, Pp. 5427-5434 , 2016.

[2] Hyung Seok Kim And Hyouk-Kyu Cha, “A Low Power Capacitive-Feedback Cmos Neural Recording Amplifier For Biomedical Applications”, IEEE ISOCC 2016, PP-279-280, 2016.

[3] Fateh Moulahcene, Nour-Eddine Bouguechal, Imad Benacer and Saleh Hanfoug, “Design of CMOS Two-stage Operational Amplifier for ECG Monitoring System Using 90nm Technology”, International Journal of Bio-Science and Bio-Technology Vol.6, No.5 , pp.55-66, 2014.

[4] Telnaz Zarifi, Chung-Ching Peng and Mohammad Hossein Zarifi,"Low-Power Amplifier for In-vivo EEG Signal Recording", IEEE, PP-19-22, 2011.

[5] Edwin Cheng Mu Lim, Xiaodan Zou, Yuanjin Zheng and Jun Tan, " Design of Low-Power Low-Voltage Biomedical Amplifier for Electrocardiogram Signal Recording", IEEE, PP-191-194, 2007.

[6] Chinmayee Nanda, J.Mukhopadhyay and Debashis MandaI," 1 V CMOS Instrumentation Amplifier with High DC Electrode Offset Cancellation for ECG Acquisition Systems", Proceedings of the 2010 IEEE Students' Technology Symposium, IIT Kharagpur, PP-21-25, 3-4 April 2010.

[7] Rakhi R, Abhijeet D. Taralkar, Vasantha M.H. and Nithin Kumar Y. B, "A 0.5 V Low Power OTA-C Low Pass Filter for ECG Detection", 2017 IEEE Computer Society Annual Symposium on VLSI, PP-589-593, 2017.

[8] Himadri Singh Raghav, B.P. Singh and Sachin Maheshwari," Design of Low Voltage OTA for Bio-medical Application", IEEE International Conference on Microelectronics, Communication and Renewable Energy (ICMiCR-2013), PP-1-5, 2013.

[9] Lipika Gupta and Amod Kumar, "Comparision on Low-Noise Neural Signal Amplifiers and Design of Current Mirror OTA for EEG", International Journal of Pure and Applied Mathematics, Volume-119, No.-12, PP-14769-14784, 2018.

[10] S S-Bustos, J S Martinez , F Maloberti And E Sanchezsinencio,"A 60-Db Dynamic-Range Cmos Sixth-Order 2.4-Hz Low-Pass Filter For Medical Applications", IEEE Transactions On Circuits And Systems, Vol. 47, PP. 1391-1398, "No.12, December 2000.

[11] Alex Wong, kong-pang pun, yuan-Ting Zhang and Chiu-Sing Choy," An ECG measurement IC using driven right leg circuit", IEEE 2006.

[12] Reid R. Harrison and Cameron Charles, "A Low-Power Low-Noise CMOS Amplifier for Neural Recording Applications", IEEE Journal of Solid-State Circuits, Vol. 38, No. 6, PP-958-965, June 2003.

[13] Alireza Karimi-Bidhendi and Omid Malekzadeh-Arasteh, "CMOS Ultralow Power Brain Signal Acquisition Front-Ends: Design and Human Testing", IEEE Transactions On Biomedical Circuits And Systems, PP-1-12, 2017.