International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No. (02), January 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Low Power Biopotential Amplifier

Anjali[1], Vandana Niranjan[2]

[1,2]Dept. of Electronics and Communication Engineering,

Indira Gandhi Delhi Technical University for Women, Kashmere Gate, Delhi (India)

ABSTRACT

Biopotential is an Electric Potential that is used to measure between two points in living cells. Biopotential Amplifier that is discussed in this paper is used in ECG. Transient and DC Analysis of Conventional and Proposed OPAMP that is used in Biopotential Amplifier all Biopotential Amplifier have been analyzed. Power Consumption is reduced by ~26 times when proposed OPAMP is used. There are three proposed Biopotential Amplifiers. Proposed 1 Biopotential Amplifier is when DTMOS technique is used in OPAMP. Using this Power is reduced by 16.90%. Transient Response and DC Response are increased by 9.01mV and 15.95mV respectively. Proposed 2 Biopotential Amplifier is when Resistors are replaced by Memristor. Using this Power is reduced by 38.59%. Transient Response and DC Response are increased by 9.19mV and 16.45mV respectively. Proposed 3 Biopotential Amplifier is when both Memristors and DTMOS technique is used in OPAMP. Using this Power is reduced by 52.95%. Transient Response and DC Response are increased by 12.45mV and 22.45mV respectively. The proposed circuits are implemented and simulated using 90 nm CMOS technology on Virtuoso (Cadence).

Keywords: Biopotential Amplifier, Memristor, DTMOS, ECG, OPAMP.

I. INTRODUCTION

Amplifier plays a vital role in Instrumentation system for measuring biopotentials. Measurements is done at low levels voltages and high source impedances. Amplifiers are used to increase signal strength that is in form of voltage generated by nerves while maintaining high fidelity. Basic Requirements of Biopotential Amplifier are high input impedances, Low output impedance, Optimal bandwidth for better SNR, Enough gain: ~ 1000 or more, High CMRR for differential input amplifiers, Quick calibration, Protection of patient from any hazard of electrical shock, Measured signal should not be distorted[1-7].

Application of Biopotential Amplifier discussed in this paper is ECG. It is a process of recording the electric activity of the heart over a period of time using electrode. It is used method in clinical environment. Measurements that is done in ECG are functions of location at which the signal is detected and it depends on the time of the signal amplitude. If different pairs of electrodes are used at different location then one can get different measurements and hence proper recording will take place[8-19].

In this paper, Transient and DC analysis of OPAMP have been analyzed. DTMOS technique is used in OPAMP and both OPAMP's are compared. Biopotential Amplifier is made using Resistors and OPAMPs. There are

IJARSE
ISSN: 2319-8354

three proposed Biopotential Amplifiers and one conventional Biopotential Amplifier. Proposed 1 Biopotential Amplifier is when DTMOS technique is used in OPAMP. Proposed 2 Biopotential Amplifier is when Resistors are replaced by memristor. Proposed 3 Biopotential Amplifier is when both memristors and DTMOS technique is used in OPAMP. Transient and DC analysis of all conventional and proposed biopotential amplifiers have been analysed. Results of both conventional and proposed (using DTMOS technique) OPAMP are compared. Power consumption is also calculated in both OPAMPs as well as in all biopotential amplifiers. Power consumption is also reduced when proposed OPAMP is used. In biopotential amplifier, power consumption is reduced in all proposed circuits. But best biopotential amplifier is when both DTMOS technique and memristor is used as power is much reduced as compare to conventional biopotential amplifier and other proposed circuits.

Rest of the paper is organized as follows: In section II, symbols, circuit diagram of Biopotential Amplifier and Proposed Techniques are described. In section III, Biopotential Amplifier and its use in ECG-Electrocardiography is described. In section IV, Memristor and DTMOS is discussed. Results are presented in section V. Comparison Tables are described in Section VI, which shows that Power is less consumed Memristor and DTMOS technique are used. Conclusion are summarized in Section VII.

II. BIOPOTENTIAL AMPLIFIER AND PROPOSED TECHNIQUES

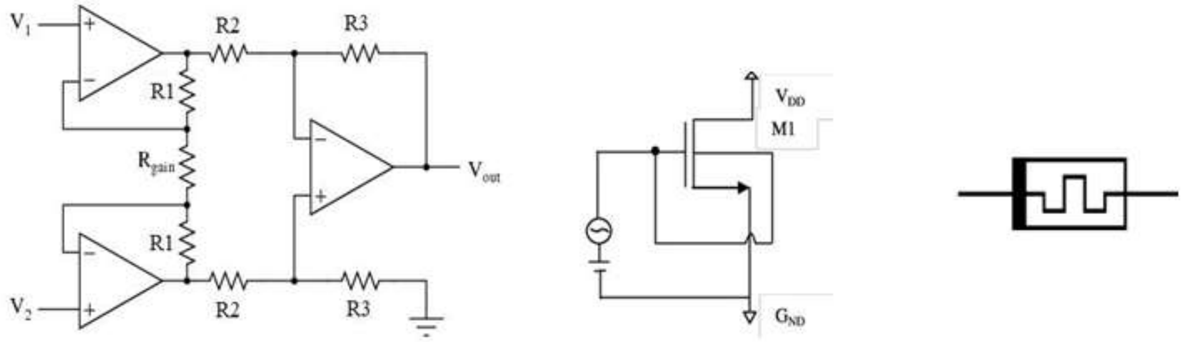


Fig. 1 (a) Biopotential Amplifier (b) DTMOS Technique (c) memristor symbol

In this paper Biopotential Amplifier shown in Fig. 1(a) is designed and then its performance is improved used Dynamic Threshold Technique (DTMOS) shown in Fig. 1(b), is used in OPAMP. In DTMOS technique gate is connected to body terminal of MOS transistor [20-21]. The proposed biopotential amplifier also uses Memristor instead of Resistors in Biopotential Amplifier to reduce Power Consumption. Memristor is combination of Memory and Resistor. It is non-volatile memory means that it remembers the amount of charge even when power is not applied. In Biopotential Amplifier, Resistors are used. Instead of Resistor, Memristor is used. Advantage of Memristor is output voltage is reduced and hence Power Consumption is also reduced. Memristor behaviour in four quadrants can be seen as in Fig.1(d).

$M = d\Phi m / dq$…….. (1) $R = dV / dI$…………(2) $C = dq / dV$…………(3) $L = d\Phi m / dI$………..(4)

IJARSE
ISSN: 2319-8354

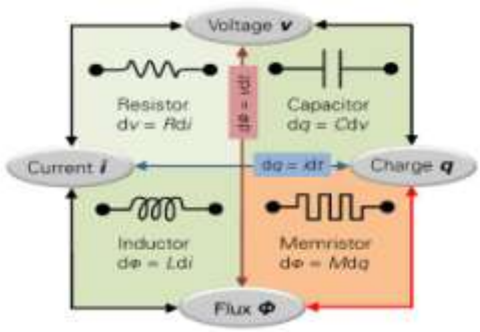


Fig. 1(d) Memristor

where M is Memristor, Φ is flux, q is charge, R is Resistor, V is voltage, I is current, C is Capacitor, L is Inductor.

III BIOPOTENTIAL AMPLIFIER AND USE IN ECG

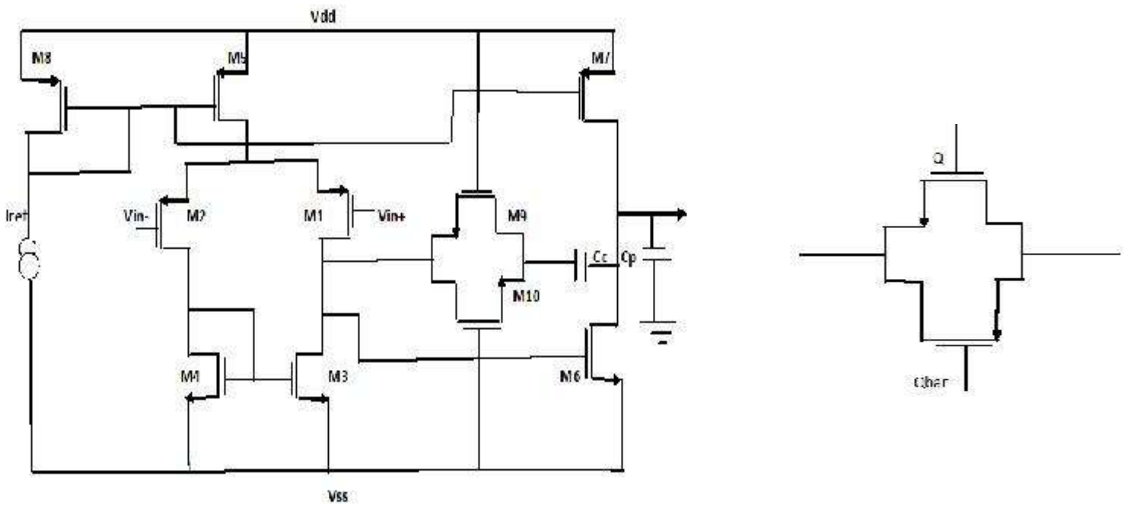


Fig. 3(a) Internal Structure of OPAMP **(b) Transmission Gate used in OPAMP**

Internal Structure of OPAMP is shown in Fig. 3(a). First of all, it is designed in Virtuoso (Cadence). Transient, DC and AC Response of this OPAMP have been analyzed. Power Consumption is also analyzed. ECG signal falls in range of 5uV - 8mV. The input pair (M1 and M2) of the input stage has been designed using large PMOS transistors and input values used are 1mV and 5mV and frequency used is 250Hz. Referance Current used in OPAMP is 0.5uA.

M5 is P-channel current source and an n-channel current mirror load (M3 and M4) are used in the input stage. The second stage of the OPAMP includes an n-channel common-source amplifier (M6) with a p-channel current source load (M7). PMOS mirror used in Internal structure of OPAMP serve as a current source while the NMOS acts as a current sink. There are two active Resistors used in Design : Referance Current and Transmission Gate. The Gate of Transistor M9 is biased with Vdd and M10 is biased with Vss.

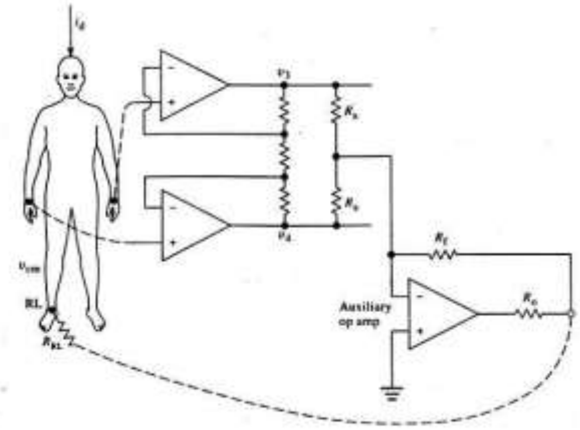


Fig. 3 (c) Biopotential Amplifier in ECG (Driven Right Leg System)

When Q is low then both transisters are off, and when Q is high then both transisters are on , giving low impedence state. The bulk potentials of the p-channel is taken at highest potential and n-channel devices are taken at lowest potentials. Here single channel MOS switch is used and its advantage over CMOS switch is that that the dynamic analog-single range in the ON state is increased. It is a process of recording the electric activity of the heart over a period of time using electrode. Problems in ECG are: Frequency distortion, Saturation or cutoff distortion, Ground loops and Interference from power lines (common mode interference) can couple onto ECG signal. To remove these problems, Driven Right Leg System Technique is used. In this technique patient right leg tied to output of an amplifier rather than ground. Common Mode Voltage is a big issue in ECG hence, negative feedback is provide to reduce common mode voltage..

Basically, right hand side OPAMP of this Biopotential Amplifier (Fig. 1(a)) acts as Differential Amplifier having gain R3/R2 and differential input resistance = 2·R2. Ideally, gain is infinite. So, to increase the gain two OPAMPs are applied at left hand side which acts as unity gain buffer if Rgain is removed. The single resistor Rgain between the two inverting inputs is a much more elegant method because it increases the differential-mode gain of the buffer pair while leaving the common-mode gain equal to 1. This increases the common-mode rejection ratio (CMRR) of the circuit. It enables the buffers to handle large common-mode signals without clipping. Another benefit of this method is that it boosts the gain using a single resistor rather than a pair. If we need a pair of Resistors then there is problem of resistor-matching. But since here single Resistor is used thus avoiding a resistor-matching problem, and hence allowing the gain of the circuit to be changed by changing the value of a single resistor. Now the gain of overall Biopotential Amplifier becomes,

$$\frac{V_{out}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{gain}}\right)\frac{R_3}{R_2} \quad (5)$$

The values of Resistors used in this paper are as follows:

Table1: Name & values of Resistors used in Biopotential Amplifier

Name of Resistors	Values
R1	10k
R2	5k
R3	10k
Rgain	5k

IV. PROPOSED BIOPOTENTIAL AMPLIFIERS

There are three Proposed Biopotential Amplifiers. Proposed 1 is when only DTMOS technique is used in OPAMP. Proposed 2 is when Resistors are replaced by Memristors and conventional opamp is used. Proposed 3 is when both DTMOS technique and Memristors are used in Biopotential Amplifier. DTMOS is a technique in which Body is connected to Gate. DTMOS is attractive for Low Power Applications. Fig 4(a) shows Internal Structure of OPAMP in proposed 1 biopotential amplifier, in which DTMOS technique is used. In MOS Transistors M5, M7, M8, M10, Dynamic Threshold Technique is used. Due to large driving ability there is low leakage current and hence output voltage and power is reduced. In today's world, Large voltage and Power is a big issue. Hence both Memristor and DTMOS technique is used so that output voltage and power is reduced. Fig. 4(b) shows proposed 2 biopotential amplifier with resistors replaced with memristors. Proposed 3 biopotential amplifier uses opamp with DTMOS technique and all resistors replaced with memristors.

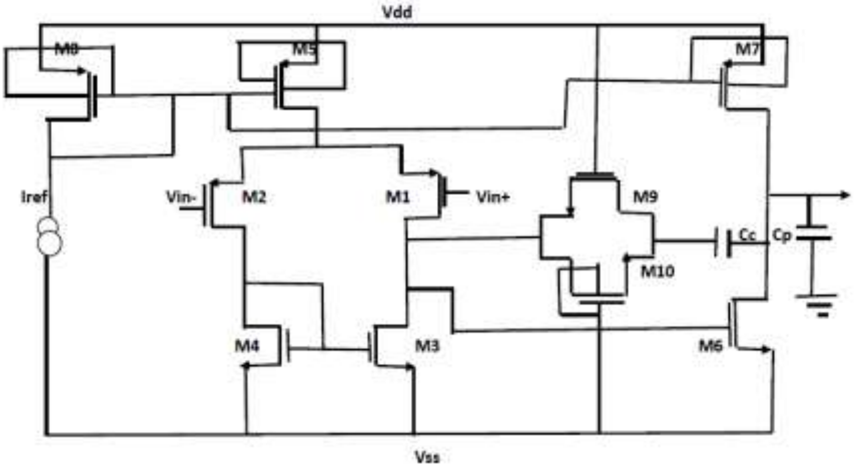


Fig. 4 (a) Opamp in Proposed 1 Biopotential Amplifier

IJARSE
ISSN: 2319-8354

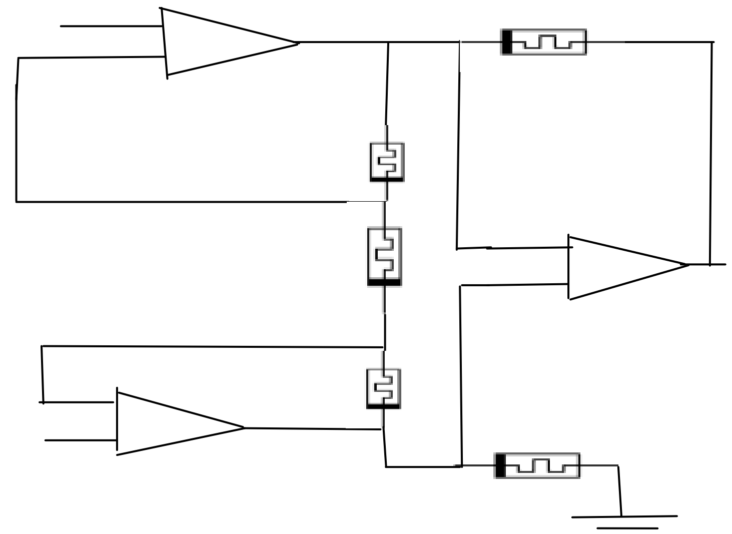


Fig. 4 (b) Proposed 2 Biopotential Amplifier

V. RESULTS

5.1 Results of Conventional OPAMP

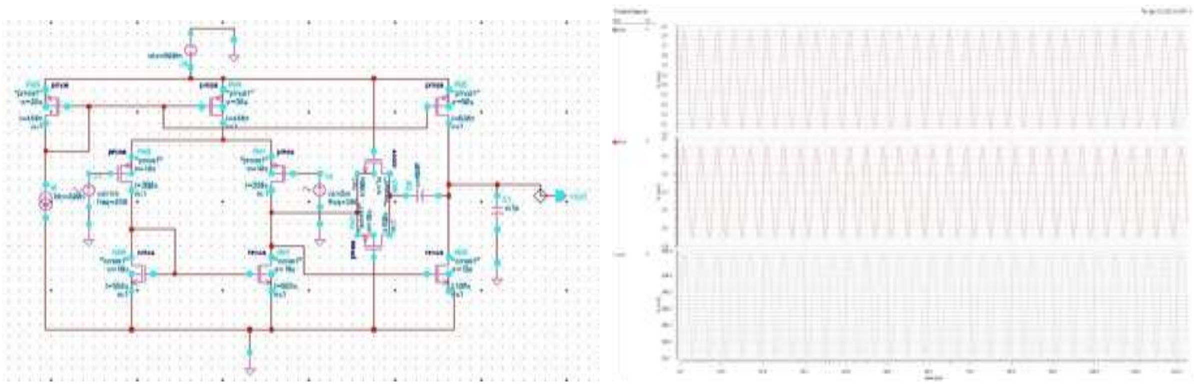


Fig. 5.1(a) Circuit Diagram of Conventional OPAMP (b) Transient Response of Conventional OPAMP

Fig. 5.1(b) shows Transient Response of Conventional OPAMP. Transient Response is find out just to check whether OPAMP that is going to be used in Biopotential Amplifier works properly or not.

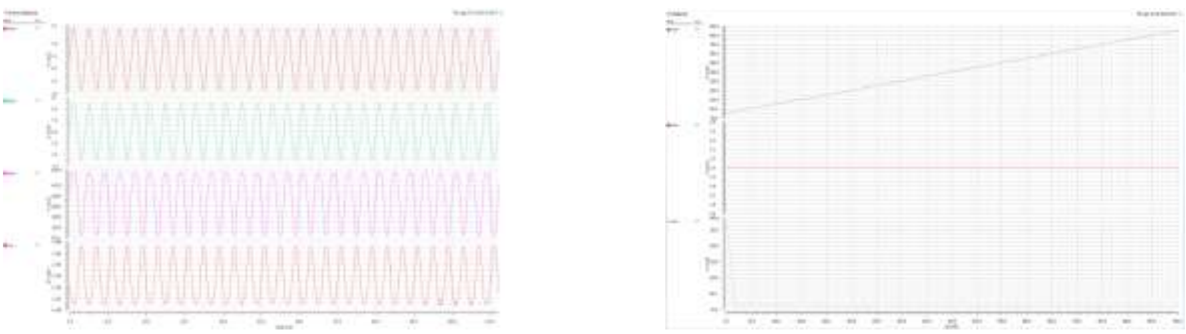


Fig. 5.1 (c) Power of Transient Response of Conventional OPAMP(d) DC Response of Conventional OPAMP

Fig. 5.1(d) shows DC of Conventional OPAMP. DC is find out just to check whether OPAMP that is going to be used in Biopotential Amplifier works properly or not.

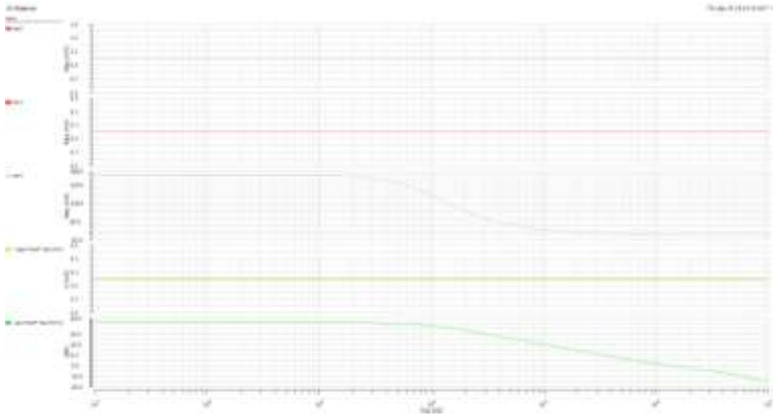
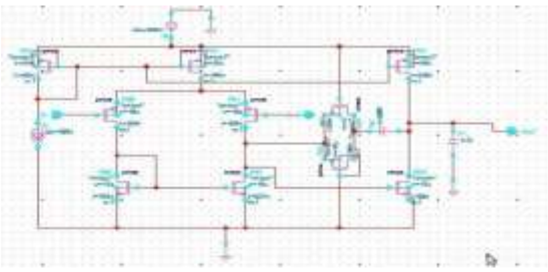


Fig. 5.1(e) Gain of Conventional OPAMP

Fig. 5.1(e) shows Gain Conventional OPAMP. If Gain of OPAMP is more than 20dB then it is considered as good OPAMP. Here Gain is 40dB and hence it is good OPAMP and can be used in Biopotential Amplifier.

5.2 Results of Proposed OPAMP



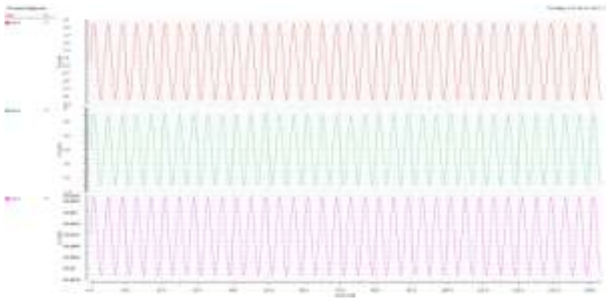
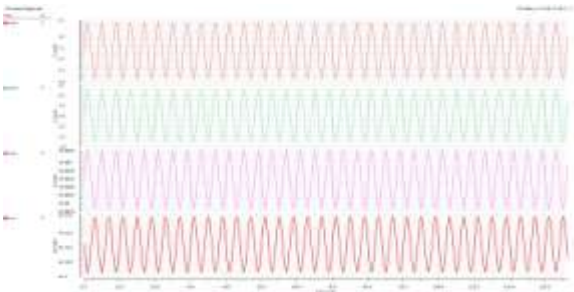


Fig. 5.2(a) Circuit Diagram of Proposed OPAMP (using DTMOS) (b) Transient Response of Proposed OPAMP (using DTMOS)

Fig. 5.2(b) shows Transient Response of Proposed OPAMP (using DTMOS). Transient Response is find out just to check whether OPAMP that is going to be used in Biopotential Amplifier works properly or not.



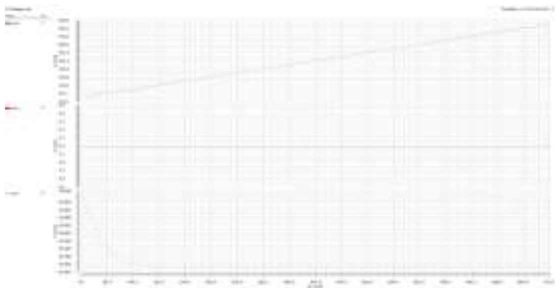


Fig. 5.2(c) Power of Transient Response of Proposed OPAMP (using DTMOS) (d) DC Response of Proposed OPAMP (using DTMOS)

Fig. 5.2(d) shows DC of Conventional OPAMP. DC is find out just to check whether OPAMP that is going to be used in Biopotential Amplifier works properly or not.

IJARSE
ISSN: 2319-8354

5.3 Simulation Results of Conventional Biopotential Amplifier

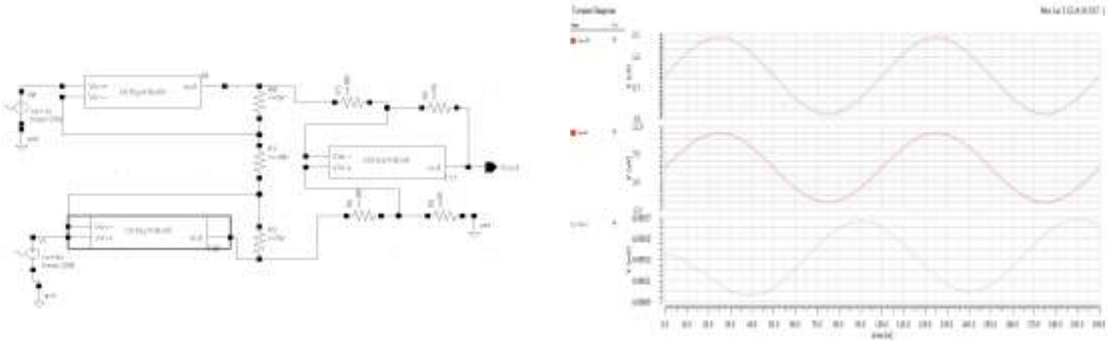


Fig. 5.3(a) Circuit Diagram of Conventional Biopotential Amplifier (b) Transient Response of Biopotential Amplifier

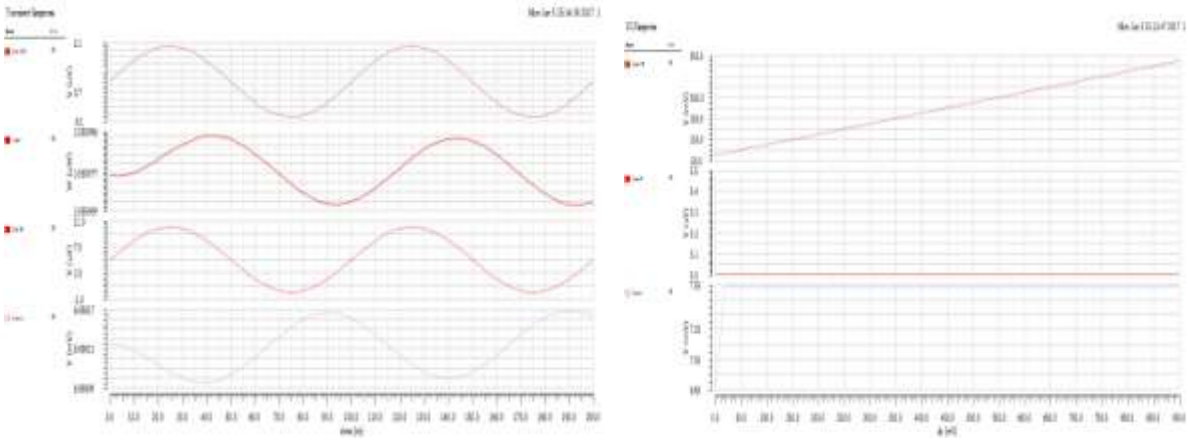


Fig. 5.3(c) Power of Transient Response of Biopotential Amplifier(d) DC Response of Biopotential Amplifier

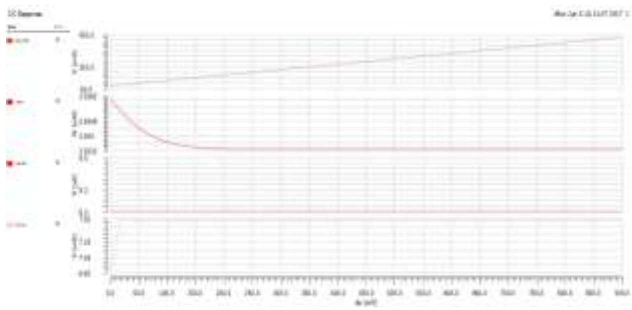


Fig. 5.3(e) Power of DC Response of Biopotential Amplifier

 IJARSE
ISSN: 2319-8354

5.4 Simulation Results of Proposed 1 Biopotential Amplifier

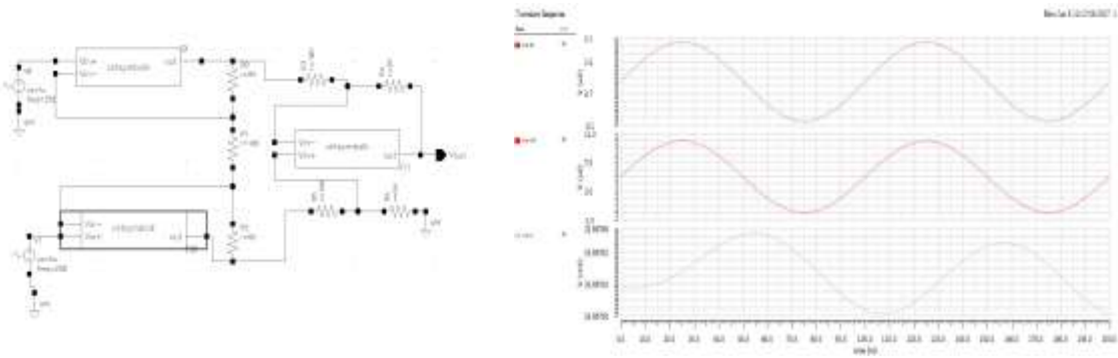


Fig. 5.4(a) Circuit Diagram of First Proposed Biopotential Amplifier (when DTMOS technique is used in OPAMP) (b) Transient Response of Biopotential Amplifier using DTMOS

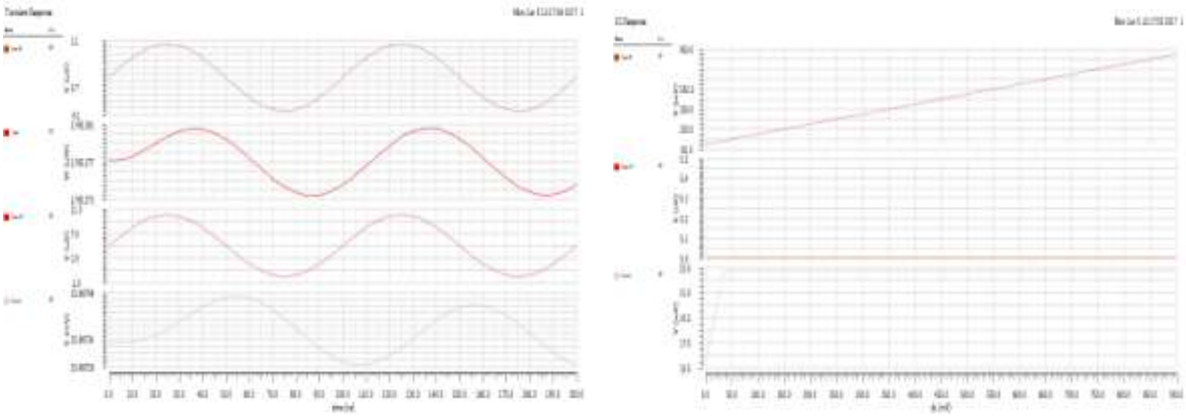


Fig. 5.4(c) Power of Transient Response of Biopotential Amplifier using DTMOS (d) DC Response of Biopotential Amplifier using DTMOS

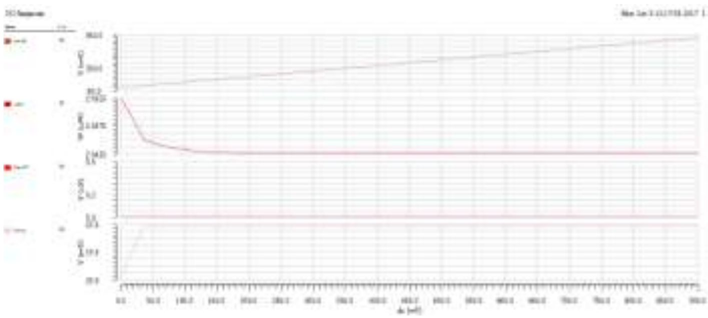


Fig. 5.4(e) Power of DC Response of Biopotential Amplifier using DTMOS

IJARSE
ISSN: 2319-8354

5.5 Simulation Results of Proposed 2 Biopotential Amplifier

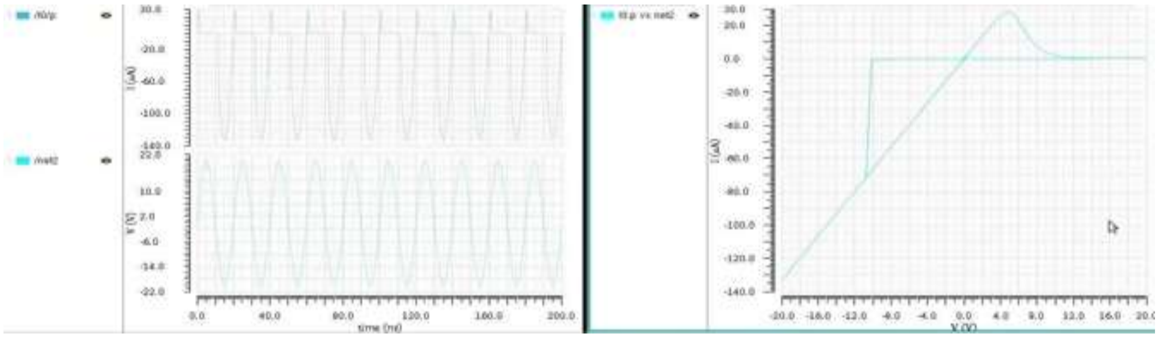


Fig. 5.5(a) I-V Characteristics of Memristor

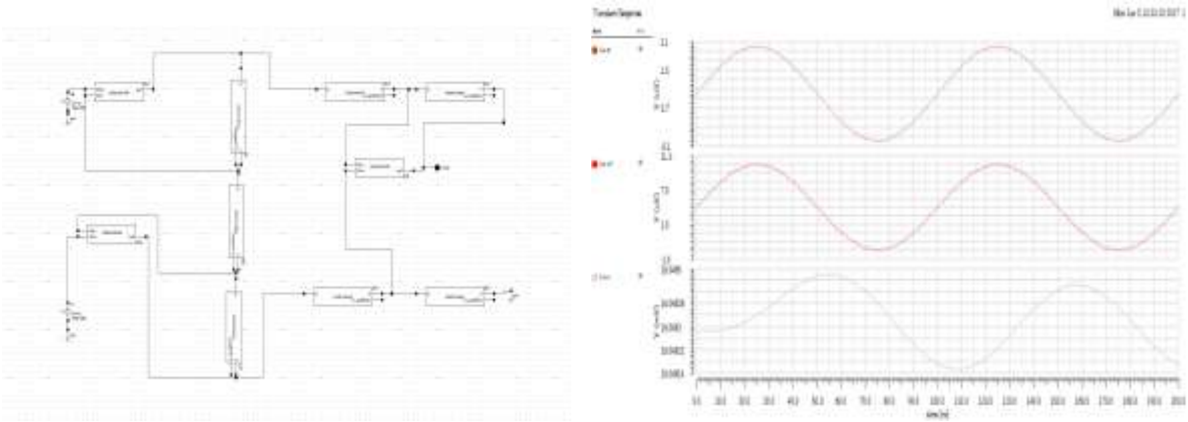


Fig. 5.5(b) Circuit Diagram of Second Proposed Biopotential Amplifier when Resistor is replaced by Memristor (c) Transient Response of Biopotential Amplifier when Resistor is replaced by Memristor

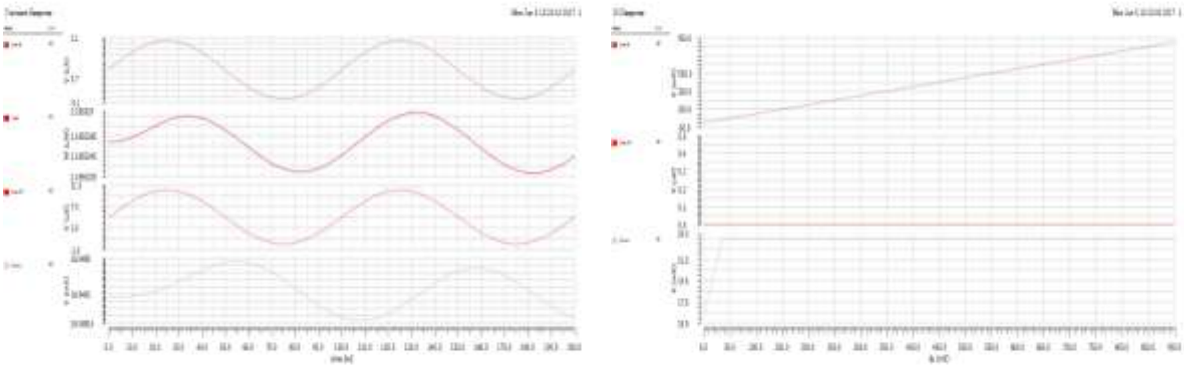


Fig. 5.5(c) Power of Transient Response of Bio Amp. when Resistor is replaced by Memristor (d) DC Response of Biopotential Amplifier when Resistor is replaced by Memristor

IJARSE
ISSN: 2319-8354

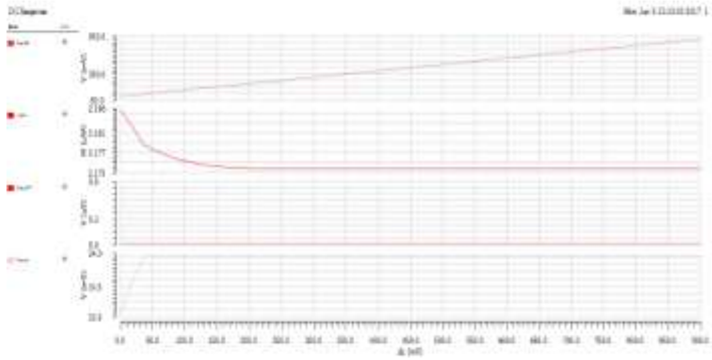


Fig. 5.5(e) Power of DC Response of Biopotential Amplifier when Resistor is replaced by Memristor

5.6 Simulation Results of Proposed 3 Biopotential Amplifier

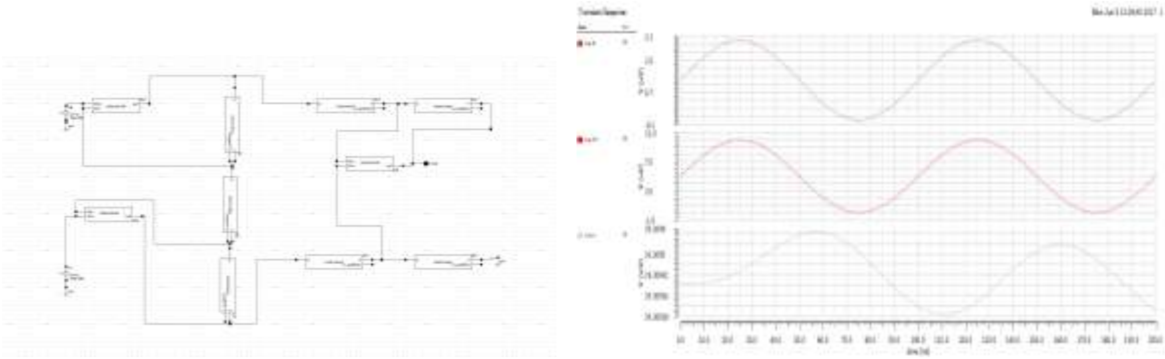


Fig. 5.6(a) Circuit Diagram of Third Proposed Biopotential Amplifier when Resistor is replaced by Memristor and also DTMOS technique is used in OPAMP (b) Transient Response of Bio Amp using DTMOS & when Resistor is replaced by Memristor

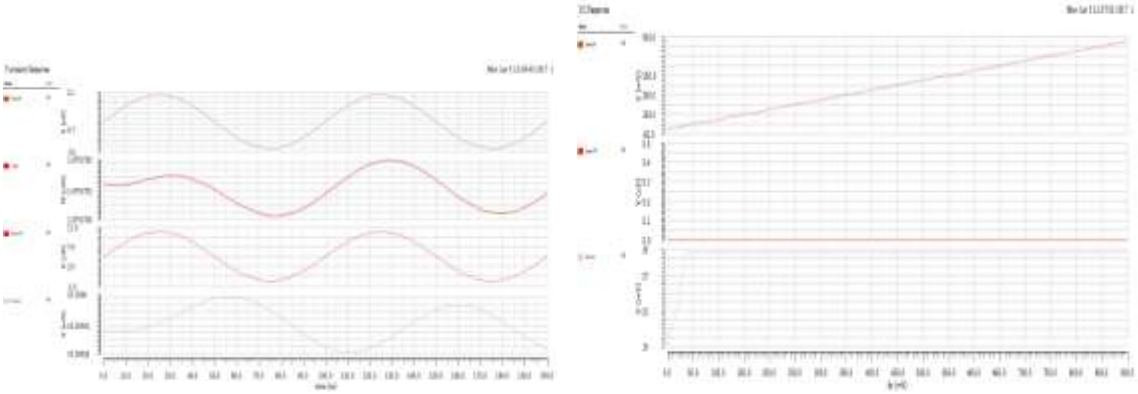


Fig. 5.6(c) Power of Transient Response of Bio Amp using DTMOS & when Resistor is replaced by Memristor (d) DC Response of Bio Amp using DTMOS & when Resistor is replaced by Memristor

International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No. (02), January 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

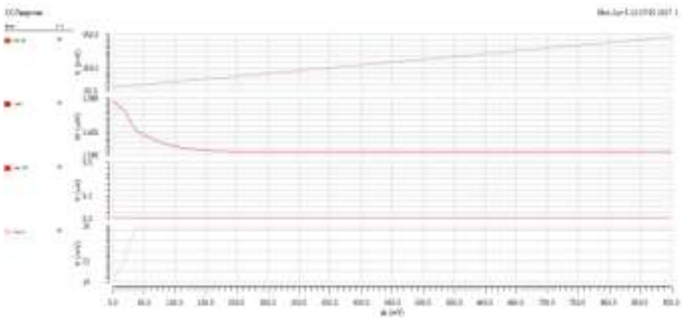


Fig. 5.6(e) Power of DC Response of Bio Amp using DTMOS & when Resistor is replaced by Memristor.

VI. COMPARISON TABLES

6.1 Comparison Table of OPAMP

Table 1: Comparison Table of OPAMP

Contents	Conventional OPAMP	Proposed OPAMP (using DTMOS technique)
Power Consumption in uW	1.16	0.044
Transient Response in mV	540	26.66
DC Response in mV	420	26.66

6.2 Comparison Table of Conventional and Proposed Biopotential Amplifiers

Table 2: Comparison Table of Biopotential Amplifier

Parameter	**Conventional Biopotential Amplifier**	**Proposed 1 Biopotential Amplifier (When DTMOS technique is used in OPAMP)**	**Proposed 2 Biopotential Amplifier (When Resistors are replaced by Memristors)**	**Proposed 3 Biopotential Amplifier (When DTMOS technique is used in OPAMP and Resistor is replaced by Memristor)**
Power Consumption in uW	3.55	2.95	2.18	1.67
Transient Response in mV	6.85	15.86	16.04	19.30
DC Response in mV	7.55	23.5	24	30
Vdd in V	0.9	0.7	0.5	0.4

VII. CONCLUSION

Power Consumption is reduced by ~26 times when proposed OPAMP is used. Conventional Biopotential Amplifier works at power supply 0.9V. Proposed 1 Biopotential Amplifier is when DTMOS technique is used in OPAMP. Using this Power is reduced by 16.90%. Transient Response and DC Response are increased by 9.01mV and 15.95mV respectively and it works at power supply 0.7V. Proposed 2 Biopotential Amplifier is when Resistors are replaced by Memristor. Using this Power is reduced by 38.59%. Transient Response and DC Response are increased by 9.19mV and 16.45mV respectively and it works at power supply 0.5V. Proposed 3 Biopotential Amplifier is when both Memristors and DTMOS technique is used in OPAMP. Using this Power is reduced by 52.95%. Transient Response and DC Response are increased by 12.45mV and 22.45mV respectively and it works at power supply 0.4V.

REFERENCES

[1] L. Chua, “Memristor- The Missing Circuit Element,” Circuits Theory, IEEE Transactions on Circuit Theory, vol. 18, no. 5, pp. 507-519, 1971.

[2] R. Pallás-Areny,J. G. Webster, ”Composite Instrumentation Amplifier For Biopotentials”, Springer, Annals of Biomedical Engineering, vol. 18, no. 3, pp 251–262, May 1990.

[3] John G. Webster, “Medical Instrumentation, Application and Design”, 3rd Edition, 2000.

[4] JJ.Carr, JM.Brown, “Introduction to Biomedical Equipment Technology”, 4nd Edition, Prentice-Hall, 2000.

[5] Budinger, T. F. “Biomonitoring With Wireless Communications,” Annual Review Biomedical Engineering, vol. 5, no. 1, pp 383–412, 2003.

[6] David J. Farwell, Nick Freemantle, Neil Sulke, “The clinical impact of implantable loop recorders in patients with syncope" European Heart Journal, vol. 27, pp 351–356, February 2006.

[7] Norhashimah Mohd. Saad, Abdul Rahim Abdullah, Yin Fen Low., "Detection of hearts block in ECG signal by spectrum and time- frequency analysis” 4th Student Conference on Research and Development, vol. 3, pp. 61–65, 2006.

[8] Y.F. Low, I. B. Mustaffa, N. B. Mohd Saad and A. H. Bin Hamidon, “Development of PC-Based ECG Monitoring System”, IEEE Research and Development, 4th Student Conference , pp.66-69, 2006.

[9] J. M. Tour and T. He, “The fourth element,” Nature, vol. 453,pp. 42-43, 1 May 2008.

[10] D. B. Strukov, G. S. Snider, D. R. Stewart, and S. R. Williams, “The Missing Memristor Found” Nature, vol. 453, no. 7191, pp. 80-83, 2008.

[11] R.S. Williams, “How we found the missing memristor,” IEEE Spectrum, vol. 45, no. 1, pp. 28-35, 1 December 2008.

[12] Y.N. Joglekar and S.J. Wolf, “The Elusive Memristor: Properties of basic electrical circuits,” Mesoscale and Nanoscale Physics, classical physics, vol. 32, pp.1-24, 13 January 2009.

[13] Pickett M. D, Strukov D. B., Borghetti J.L.,Yang J.J., Snider G.S., Stewart D.R., Williams R.; "Switching dynamics in titanium dioxide memristive devices", Journal of Applied Physics, vol. 106, pp. 074508, 2009.

[14] W.-S. Wang, Z.-C. Wu, H.-T. Huang and C.-H. Luo, "Low Power Instrumental Amplifier for Portable ECG", IEEE Circuits and Systems International Conference, vol. 23, no. 5, pp. 1-4, 2009.

[15] C.-T. Ma, P.-I. Mak, M.-I. Vai, P. Mak, S.-H. Pun, W. Feng and R.P. Martins, "A 90nm CMOS Bio-Potential Signal Readout Front-End with Improved Powerline Interference Rejection", IEEECircuits and Systems, vol. 64, no.4, pp. 665-668, 2009.

[16] H.-C. Chow and B.-S. Tang, "A high Performance Current-mode Instrumentation Amplifier For Biomedical applications", 2nd International Conference on Signal Processing Systems, vol. 978, no. 1, pp 4244-6893, 2010.

[17] C. Ken and L. Xiaoying, "A Zigbee Based Mesh Network for ECG Monitoring System", Bioinformatics and Biomedical Engineering (iCBBE), vol. 65, no. 6, pp.1-4, 2010.

[18] Muhammad Zahak Jamal, "Signal Acquisition Using Surface EMG and Circuit Design Considerations for Robotic Prosthesis", INTECH World's Largest Science, Technology and Medicine Open Book Access, 2012.

[19] Fateh Moulahcene, Nour-Eddine Bouguechal, Imad Benacer and Saleh Hanfoug," Design of CMOS Two-stage Operational Amplifier for ECG Monitoring System", Vol.6, No.5, pp.55-66, 2014.

[20] Vandana Niranjan and Maneesha Gupta, "An Analytical model of the Bulk-DTMOS transistor", Journal of Electron Devices (JED), Vol.8, pp. 329-338, 2010

[21] Vandana Niranjan, Akanksha Singh, Ashwani Kumar, "Dynamic Threshold MOS transistor for Low Voltage Analog Circuits" International Conference on Recent Trends & Issues in Engineering and Technology (ICRTIET), Modinagar, India, August 30-31, 2014.