International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 03 | Mar 2023 www.irjet.net p-ISSN: 2395-0072

DESIGN AND IMPLEMENTATION OF CURRENT MIRROR SYMMETRICAL OPERATIONAL TRANSCONDUCTANCE AMPLIFIER FOR ECG SIGNAL

Dr.V.V.K.D.V.Prasad[1], B.R.B Jaswanth[2], Pinjala Venkata Kalyani[3], Uddanti Kavya Sri[4], Naga Sai Srinivas Matta[5], Potharaju Rohit Sai Teja[6]

[1] Professor & Additional Controller of Examinations,Department of Electronics and Communication Engineering, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru
[2] Assistant Professor, Department of Internet Of Things, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru
[3,4,5,6] Scholars, Department of Electronics and Communication Engineering, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru

---***---

Abstract: *A sudden cardiac arrest (SCA) is a major cause which accounts to 50% of deaths in industrialized nations. Analysis of the ECG signal gives the diagnosis of number of heart diseases. For the interpretation of these ECG signals Operational Transconductance Amplifier(OTA) is suitable. In this paper, a design of a robust amplifier namely Operational Transconductance Amplifier (OTA) is considered for amplifying the ECG signal. It is operated in the operating frequency range of an ECG around 150Hz[5]. Frequency response analysis is also planned to carry out for estimating the effective bandwidth and gain requirements suitable for the ECG signals and layout of the design is planned to draw using cadence virtuoso analog design environment. ECG signal collected from patient is applied to OTA and is amplified with low noise so that we can detect low heart beat also. Because of OTA amplifier one can diagnose the heart disease as early as possible and reduce the death rate due to heart diseases.*

Keyword: Electrocardiogram(ECG), Operational trans conductance amplifier (OTA), frequency response, gain, cadence virtuoso.

1 .INTRODUCTION :

A sudden cardiac arrest is a major cause which accounts to 50% of deaths in industrialized nations. Regular monitoring of heart beat of heart patients can reduce these deaths due to sudden cardiac arrests. The signal from the heart is called as ECG signal. This ECG signal represented as voltage vs time. By using electrode which is placed on the skin of the patient, one can get the signal from the heart. Generally, the ECG signal have very low voltage 0.5-4mv so analysis of this signal is difficult. The frequency range of ECG signal is 0.01-250Hz.

In this paper, a design of a robust amplifier namely OTA is considered for amplifying the ECG signal. OTA becomes basic building block for so many circuits. OTAs are used as key element for circuits which require voltage control. It is used in open loop configurations without negative feedback , so it provides high output impedance and it can be used as a high impedance differential input stage. OTA consists of three inputs two for input voltages and other for bias current which control the transconductance of the amplifier. OTA can be used as analog to digital converter, digital to analog converter, oscillator, mixer ,etc.

Several popular techniques are there to implement OTA such as folded cascode OTA, AC coupled staking OTA [6], doublet OTA, current mirror symmetrical OTA, two stage OTA. A current mirror symmetrical OTA design is proposed in this paper. Current mirror OTA has several advantages which are suitable for ECG applications. Current mirror OTA consists of 8 transistors 4 NMOS and 4 PMOS. It The OTA produces a output waveform which is out of phase with the input. Current mirror OTA was designed using cadence virtuoso ADE in 45nm technology.

2 .RESEARCH METHOD :

2.1. Current Mirror Symmetrical OTA

The OTA was implemented OTA in 45 nm CMOS technology using current mirror symmetrical technique[1]. This approach was chosen due to its various benefits, such as higher gain bandwidth, larger transconductance, and a faster slew rate. The current mirror OTA was simulated in cadence virtuoso ADE.

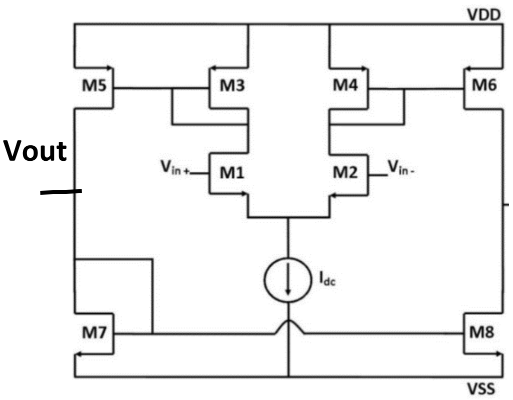

Fig 1: current mirror symmetrical OTA circuit diagram

The width of M1 & M2 transistors is 2µm and length is 1µm, width of M3 & M4 transistors is 3µm and length is 1µm, width of M5 & M6 transistors is 6µm and length is 1µm, width of M7 & M8 transistors is 0.24µm and length is 1µm[1].

From the above it shown that the circuit requires 4 ratios of W/L only so, the implementation of this topology is easy.

2.2. Current Mirror OTA Specifications

OTA was designed in 45nm CMOS technology[1]. This OTA was designed to use for ECG application. So for ECG signal there should be several specifications for proper amplification[1][3]. The following are the specifications of the current mirror OTA[1][7],

Voltage Supply - VCC +500mv,

VEE -500mv

Bias current - 1mA

Gain - >40dB

Input noise - <4mV/Hz

Power consumption - <10µW

Slew rate - >10V/µs

CMRR - >100

3.CIRCUIT SCHEMATIC IN CADENCE

The schematic of the designed OTA is shown in fig.2 was drawn in cadence virtuoso ADE. All the transistors were taken from the gpdk045 technology library. After this symbol as

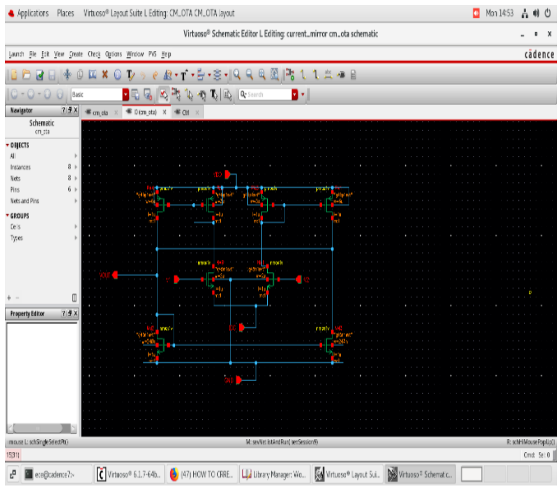

Fig 2: schematic of current mirror OTA drawn in cadence

shown in fig. 3 was created for the current mirror OTA with 3 inputs, 1 output and 2 supply pins[1][3]. Two symbols were created one for differential input pair and other for common input pair. Two supply voltages were given positive voltage of 500mv for VDD and negative of -500mv for VEE. IDC for both the OTAs was given 0A. For differential input a sinusoidal signal of amplitude 2mv and frequency of 150 Hz was applied to one input and the other input was grounded. For common input sinusoidal signal of amplitude 2mv and frequency of 150 Hz was applied to both the inputs of the OTA.

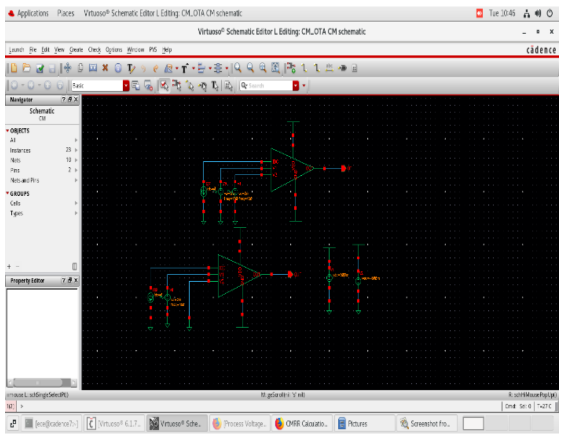

Fig 3: symbol created for current mirror OTA

4. RESULTS

4.1 Transient Analysis

For transient analysis OTA was simulated using cadence virtuoso analog design environment. The transient analysis for differential input is shown in fig.4. A sinusoidal signal of amplitude 2mv and frequency of 150 Hz is applied to one input of the OTA and other input is grounded. The amplitude and frequency of input signal were set in the manner similar to the ECG signal. It generates an amplified output with amplitude nearly 700mv.

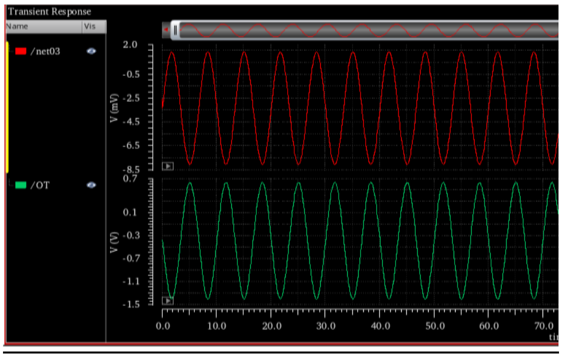

Fig 4: transient analysis for differential input

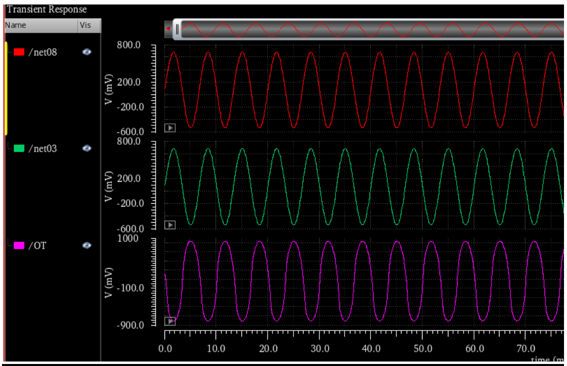

Fig 5: transient analysis for common input

The transient analysis for common input is shown in fig.5. A sinusoidal signal of amplitude 800mv and frequency of 150 Hz was applied to both the inputs of OTA. The OTA generates a amplified output with amplitude nearly 1V. The output current values for different input voltages are shown in table 1.

Input voltage(mV)	Input current(mA)	Output voltage(V)	Output current(mA)
2	0.02	-1.1	-11
-2.5	-0.025	0.1	1
-8	-0.08	0.6	6
-6	-0.06	0.3	3
1	0.01	-0.4	-4

Table 1*:* input and output currents for different voltages

4.2 AC Analysis

For AC response the OTA was simulated using cadence virtuoso analogue design environment. To efficiently amplify the ECG signal as per the specifications, the OTA must generate an open loop gain of over 40dB. To test the differential gain, an AC signal with a 1V amplitude was applied to one input, and the other input was set to 0V. The OTA produced a differential input gain of 42dB as shown in

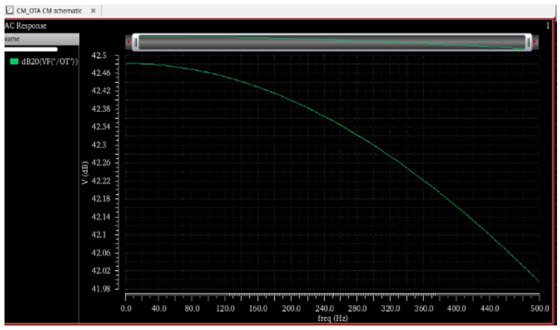

Fig 6 : differential input gain

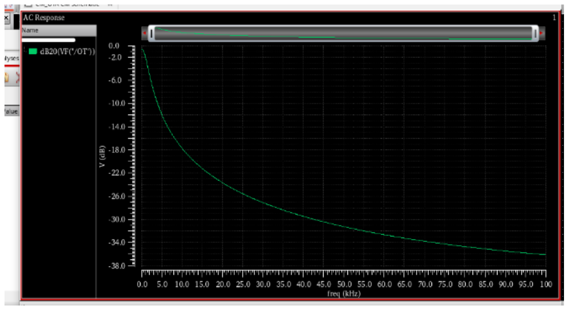

Fig 7 ***:*** common input gain

fig.6. For common input gain, sinusoidal input of amplitude 1V applied to both the inputs and the common mode gain is shown in fig.7.

4.3 Power Consumption

The power consumption of the OTA was calculated during the transient analysis using cadence virtuoso ADE. The power can be calculated from the power wave fig. 8. The OTA consumed 151nW power from ±0.5V power supply. This OTA is used for ECG signals which is of very low voltages, the size of the OTA will be very small, it will be portable and it is battery operated so the power consumption will be low[4][6]. The power consumption met the design specifications.

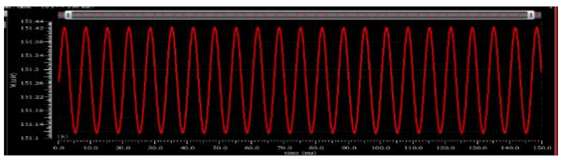

Fig 8 : power wave of the current mirror OTA

By using calculator tool in the cadence tool we can calculate the power from the power waveform. It will give the exact power value. The calculated power value is shown in fig. 9.

	Expression	Value
1	average(getData...	151.3E-9

Fig 9 *:* power consumption of the current mirror OTA

4.4 Noise Analysis

The noise response of OTA is shown in fig. 10. The OTA generated 2.2mV/Hz at 1 Hz frequency. OTA met the design specifications. At MHz frequencies, the noise will be 0V. For high frequencies the input noise is very less. As the voltage and frequency of ECG signal is very low, noise should be very less for proper amplification of the signal so it is necessary to choose an amplifier which eliminates more noise. As the OTA generated less noise it is suitable for ECG applications.

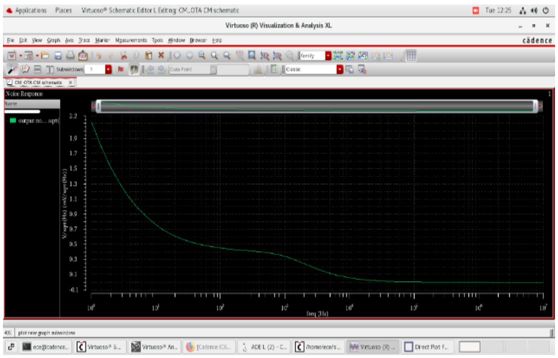

Fig 10 *:* noise analysis of current mirror OTA

4.5 DC Analysis

For DC response the OTA was simulated using cadence virtuoso ADE. The response of the OTA is shown in fig. 11.

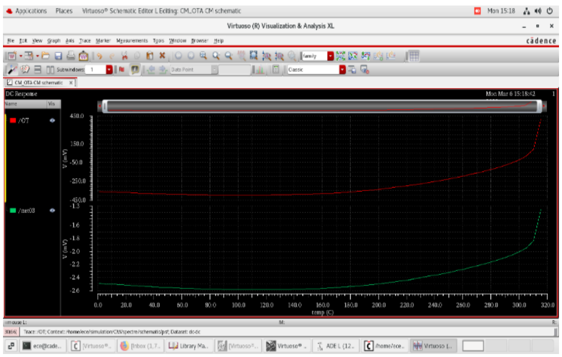

Fig 11 : DC analysis of current mirror OTA

4.6 Slew Rate

The slew rate of the OTA was calculated using cadence virtuoso ADE. For slew rate firstly, transient analysis was performed after that by using calculator tool and using slew rate function there the slew rate will be calculated. The slew rate of the current mirror OTA obtained is shown in fig. 12.

	Expression	Value
1	slewRate(VT("/O...	702.0

Fig 12 : slew rate

5. LAYOUT DESIGN

Finally, we drawn layout for current mirror OTA. The layout was drawn using cadence virtuoso ADE. By using 45nm technology layout was drawn. From schematic layout was drawn. In cadence, for layout design launch layout XL. After that, select the wiring lengths and widths. Then connect the components using polysilicon and metal layers.

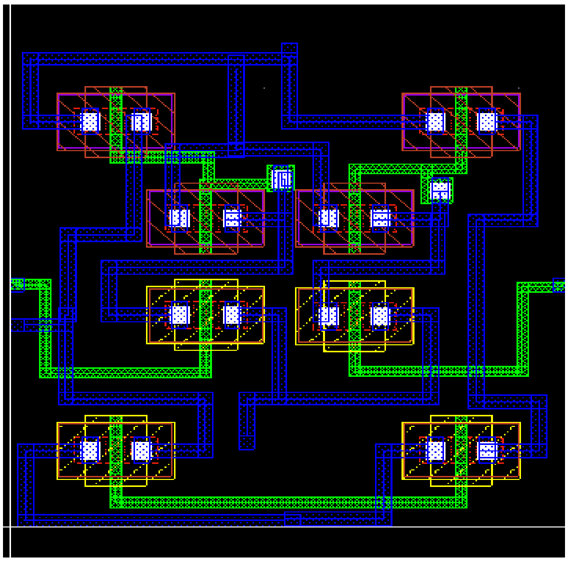

Fig 13 : layout of the current mirror OTA(with transistor layers)

The layout of the current mirror OTA with transistor layers is shown in fig. 13. It consists of 4 PMOS and 4 NMOS transistors. The source and drain terminals were connected with metal layers and the gate terminal was connected with polysilicon layer. The input, output pins and power supply pins were created with metal layer. The PMOS transistors are represented with pink colour and the NMOS with yellow colour.

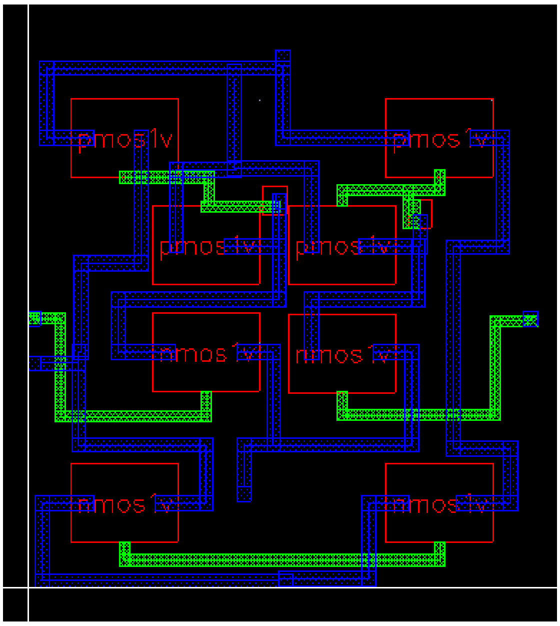

Fig 14 : layout of current mirror OTA

The metal layer represented with blue colour and the polysilicon layer represented with green colour. The layout of the OTA without transistor layers is shown in fig.14. In this transistor layers are not visible, transistors are represented as rectangular boxes and highlighted with red colour with the transistor name in the middle. After giving the connections as per the circuit, DRC and LVS were performed.

6. PARAMETERS COMPARISON

The results obtained from the analyses were compared with specifications and tabulated below in table 2.

Parameter	**Specifications**	**Our work**	**CMOS OTA[2]**
Voltage supply (V)	±0.5	±0.5	±1
Power consumption (mW)	<10	0.151	1.440
Slew rate (V/ µs)	>10	702	-
Gain (dB)	>40	42	38.43
Noise (mV/Hz$^{1/2}$)	<4	2.2	0.22

Table 2*:* comparison of parameters

From table 2, it is clear that the OTA's gain 42dB is greater than the desired gain which is 40dB. The power consumption of the OTA is 151nW which is lower than the 10µw. The obtained slew rate of the OTA is 15V/µs which exceeds the desired slew rate 10V/µs. The input noise produced by the OTA was 2.2mV and it met the design specification. The power consumption is the important factor for ECG applications, hence the power consumption is very low so this OTA is suitable for ECG applications. This OTA met the design specifications, it is more suitable for ECG signal.

8. CONCLUSION

This paper describes the design, simulation, and analysis of current mirror symmetrical OTAs using 45nm technology in the Cadence Virtuoso ADE. Firstly, schematic was drawn and then symbol was created, after that the OTA was simulated. The OTA was simulated using ECG signal equivalent having frequency of 150Hz. Transient analysis, DC analysis, AC analysis, power analysis were performed and slew rate also calculated. The OTA produced a gain of 42dB and consumed only power of 151nW from ±500mv. It produced input noise of 2.2mV. The slew rate of the OTA was 15V/µs. The simulation results were compared with the design specifications. The design specifications were met. Finally, layout of the current mirror symmetrical OTA was drawn using 45nm technology in cadence virtuoso ADE and DRC, LVS were performed. Hence, it met the design specifications and it consumed less power[4] so it is suitable for ECG signals[1].

REFERENCES

[1] Aiman Ehsan, Siti Hawa Ruslan, "Design and analysis of current mirror OTA in 45nm and 90nm CMOS technology for biomedical application," *Bulletin of Electrical Engineering and Informatics* Vol. 9, No. 1, pp. 221~228, Feb 2020.
doi: 10.11591/eei.v9i1.1860, ISSN: 2302-9285

[2] Zekun Zhang , Fanxiang Meng, and Luyuan Fan, "Design of ECG Front End Amplifier Based on CMOS OTA," *Journal of Physics: Conference Series,* Jul 2021, doi:10.1088/1742-6596/1907/1/012002.

[3] P. Nijhara, P. Singh and P. Gaur, "Design and Simulation of Operational Transconductance Amplifier Using Wilson Current Mirror," *2021 8th International Conference on Signal Processing and Integrated Networks (SPIN),* pp. 708-713, Jun 2021 , doi: 10.1109/SPIN52536.2021.9565943.

[4] A. Kumar, S. L. Tripathi, C. Verma, M. S. Raboaca, F. M. Enescu and T. C. Mihaltan, "Design and Analysis of Low

Power Bio-amplifier with Current Mirror Topology at CMOS 45nm Technology Node," *2022 14th International Conference on Electronics, Computers and Artificial Intelligence (ECAI),*pp.1-5,Jul 2022, doi:10.1109/ECAI54874.2022.9847492.

[5] N. Strodthoff, P. Wagner, T. Schaeffter and W. Samek, "Deep Learning for ECG Analysis: Benchmarks and Insights from PTB-XL," *in IEEE Journal of Biomedical and Health Informatics*, vol. 25, no. 5, pp. 1519-1528, May 2021,
doi: 10.1109/JBHI.2020.3022989.

[6] Bijesh Kumar Singh, Gori Shankar , Dr. Bharat Bhushan Jain,"An Overview on Low Voltage Low Power Operational Transconductance Amplifier (OTA) for Biomedical Application,"*in International Journal of Engineering Trends and Applications (IJETA)*, Volume 8 Issue 3, May-Jun 2021.

[7] N. R. Jangam and S. Ajmera, "Design and Implementation of Ultra low power CMOS based Operational Trans-conductance Amplifier (OTA) for Biomedical Applications,"*2nd International Conference for Emerging Technology (INCET), Belagavi, India*, pp. 1-4, Jun 2021,
doi: 10.1109/INCET51464.2021.9456426.