CMOS Trans Conductance based Instrumentation Amplifier for Various Biomedical Signal Analysis

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Abstract

Feed forward design techniques for the Trans-conductance operational amplifier removes the barriers of operating frequencies. It is now possible to design amplifiers with large the Trans-conductance that operates at Giga hertz frequency range. There are several Trans-conductance amplifiers used to design a medical and Industrial application that helps in processing various bio medical signals such as Electrocardiographs, Electroencephalographs, Electromyograms and several others. The proposed paper shows the implementation of an instrumentation amplifier using CMOS based the Trans-conductance operational amplifiers also the processing of biomedical ECG, EEG and EMG signals. The CMOS process technology helps to integrate complex circuits on minimal surface area. The Trans-conductance instrumentation operational amplifiers has features includes noise reduction, low DC offset, High output impedance and Common Mode rejection Ratio values. The circuit implementation and simulations has been done on Electronic Design and Automation tool with 0.13μm CMOS process technology.

Key Words: Transconductance, Instrumentation Amplifier, CMOS Process, Biomedical Signals, Bio-potential Signal, CMRR, Frequency Response, Signal Measurement.

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Introduction

A high performance CMOS instrumentation amplifier design becomes popular choice for biomedical circuit design as such designs offers low voltage, low power operating parameters and minimal chip area for component integration. [1-3], [5-6], [9] Biomedical signals [7] also known as bio potentials. These are very weak amplitude electrical signal also are of low frequency. It is therefore important to have some amplifier circuit to perform the process of amplification for these weak electrical bio potentials. The amplifier used in the process of bio potential amplification is called as bio potential amplifier [7-8], [9], [17].

There are various bio potential amplifiers available which include amplifiers like differential, isolation, operational and chopper amplifier [8]. These amplifiers meet some crucial requirement to work with low frequency and voltage bio potentials. These requirements include the amplifiers must have high value of input impedance. The minimum value of input impedance for these amplifiers is 100 MΩ. These bio potential amplifiers should be capable to work in low frequency range as the bio potentials possess lower frequencies and the frequency ranges from Hz to kHz only. It should provide large gain values so that the weak amplitude bio potentials should easily be seen on display devices and these amplifiers should be implemented with proper protection and isolation sub circuitry to avoid any artifacts and mismatch. In bio medical circuit design, the circuit design using differential amplifiers and operational amplifiers are preferred over other bio potential amplifiers.

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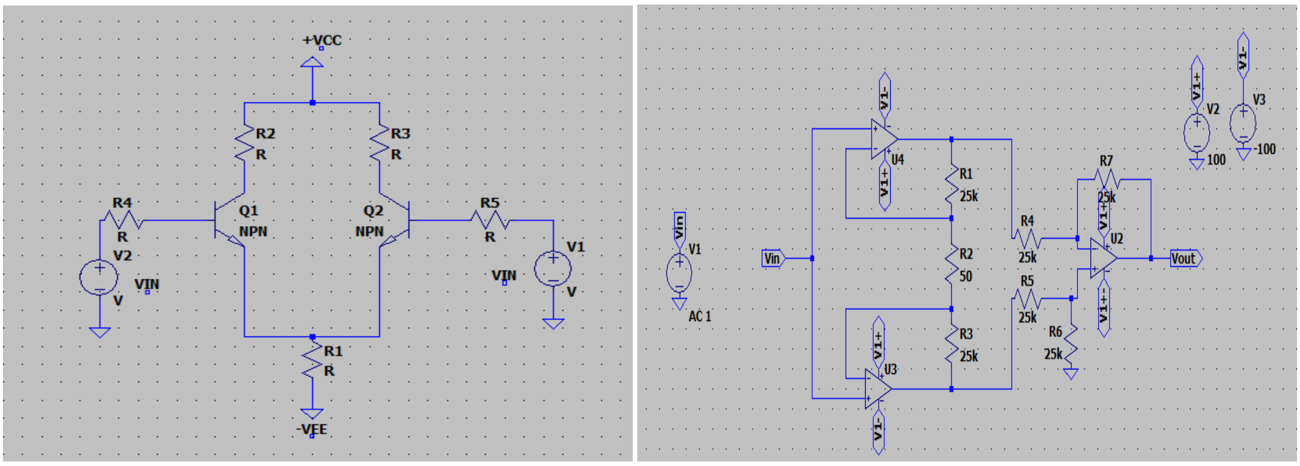
Differential amplifier has an ability to remove interference or common mode signals generated from the electrode connected to human body to record motion of the heart. Hence differential amplifiers provide high value of CMRR. Differential amplifier also provides good stability [7-8]. Though such amplifier circuit has better ability for interference rejection but it lacks having enough input impedance. To overcome the limitation of the value of input impedance and to achieve large CMRR value operational amplifier based instrumentation amplifier is used in bio potential amplifier circuit implementation.



(a) (b)

Figure 1. (a) Differential Amplifier schematic (b) Instrumentation Op-Amp schematic

Trans-conductance Operational Amplifiers

Trans-conductance operational amplifier [10], [14], [19] or OTA provides wide signal bandwidth for many amplifier circuits. In this amplifier, input voltage that is applied at the op-amp produces output current. There is an additional amount of current present that controls the trans-conductance of operational amplifier.

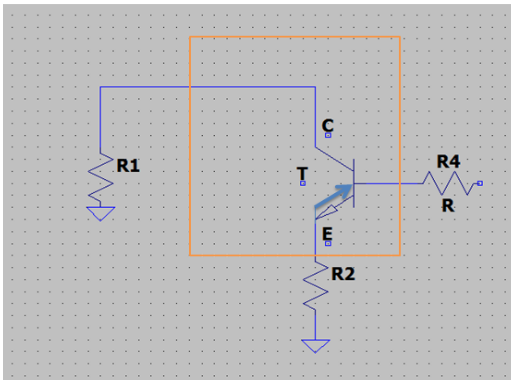


Figure 2. Basic Operational Trans-conductance Circuit Architecture

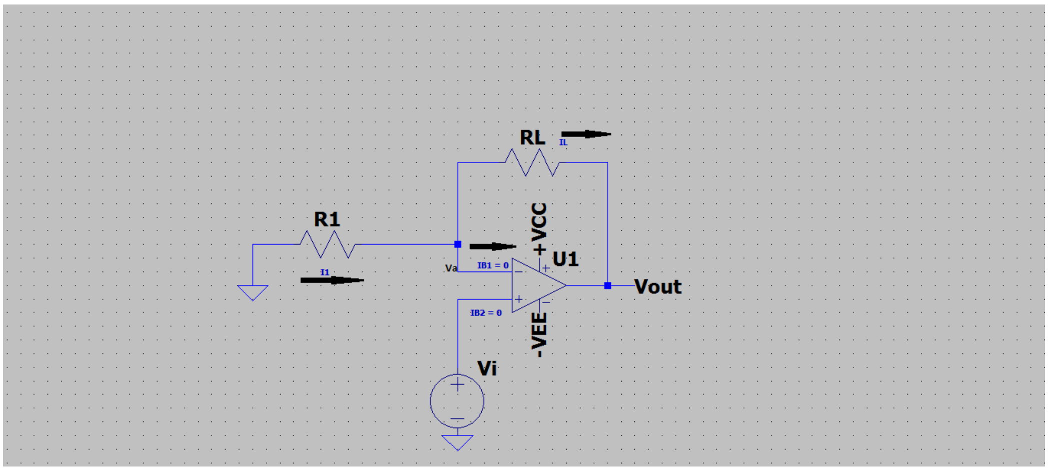


Figure 3. Trans-conductance Operational Amplifier

From figure 3, the equation for the output current from this circuit is given as,

At point 'a'

$$V_a = V_i \qquad (1)$$

and

$$I_{B1} = I_{B2} = 0 \qquad (2)$$

Using Kirchhoff's current law, we have,

$$I_1 = I_{B1} + I_L \qquad (3)$$

From equation (2),

$$I_1 = I_L$$

Current through Resistor R_1 is given by equation,

$$I_1 = \frac{V_i}{R_1}$$

Instrumentation Amplifiers

Development of efficient instrumentation amplifier [11], [12] in CMOS fabrication process has many advantages such as Lower voltage and power requirement, devices with more noise immunity, ability to integrate complex circuitry on single silicon chip and easy trans-conductor implementation. It is one of the integrated circuit used for extremely weak signal amplification. As it is more immune to noise removal, it is used in biomedical systems to accurately measure the bio potential signals. Instrumentation amplifier exhibits following important characteristics.

- Stable and accurate gain
- High CMRR
- High value input impedance, low value output impedance
- High slew rate

Traditional Instrumentation amplifier using 2 stage op-amp circuits is given below. It consists of two inverting and non-Inverting op-amps at the input stage and one output op-amp.

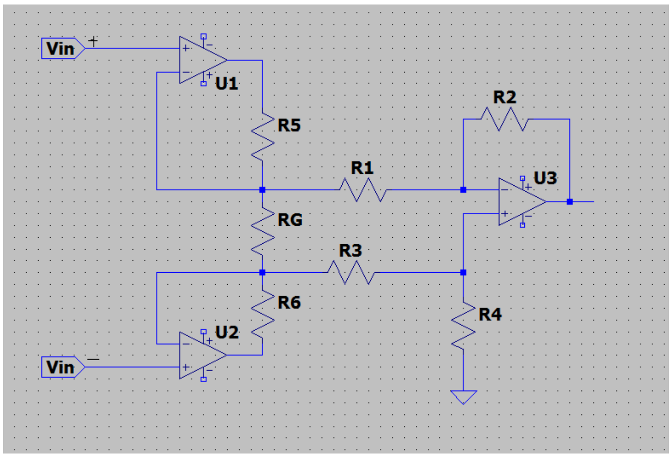


Figure 4. Traditional 2 stage Op-Amp Instrumentation Amplifier

The output voltage from the circuit shown in figure 4 is given by,

$$V_{out} = \frac{R_2}{R_1}\left(\frac{2R_5}{R_G} + 1\right)(Vin_+ - Vin_-)$$

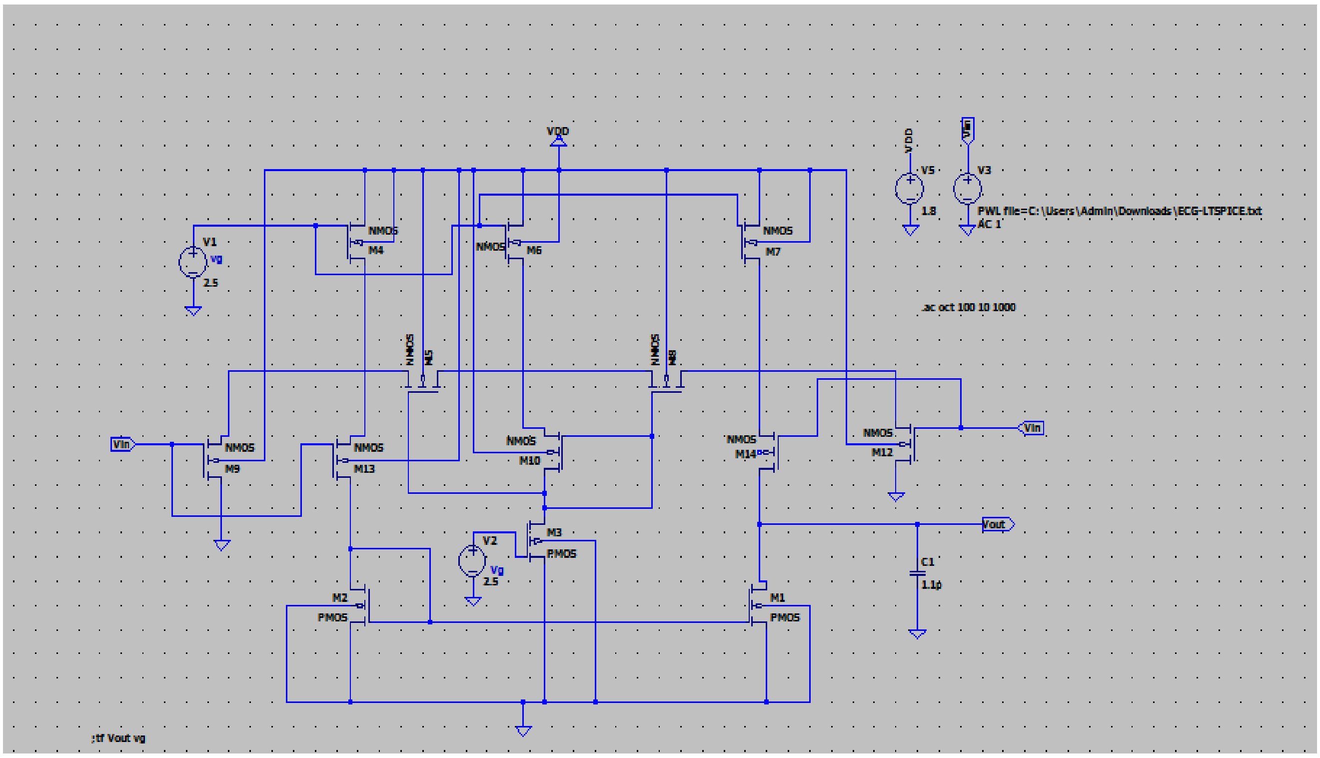


Figure 5.1. OTA Based CMOS Amplifier

Implementation

The proposed work is related to verify the capability of an OTA based instrumentation amplifier. The schematic of OTA based CMOS Amplifier is shown in figure 5.1. Three different bio-potential source signals such as ECG, EEG and EMG are taken for this purpose. The piecewise linear voltage files are applied to the input of an instrumentation amplifier. The amplification for these source signals is analysed. Similarly some common mode noise signals are added with these source signals.

Proposed circuit implementation uses three wideband OPA861 operational trans-conductance amplifiers as shown in figure 5.2. A differential amplifier input stage is constructed using two OTA's. Remaining trans-conductance amplifier is used for current reversal. A current flow through differential amplifier is out of phase with the current flows from capacitor C. the op-amp based integrator is used for current collection. To avoid propagation delay RC circuit is connected.

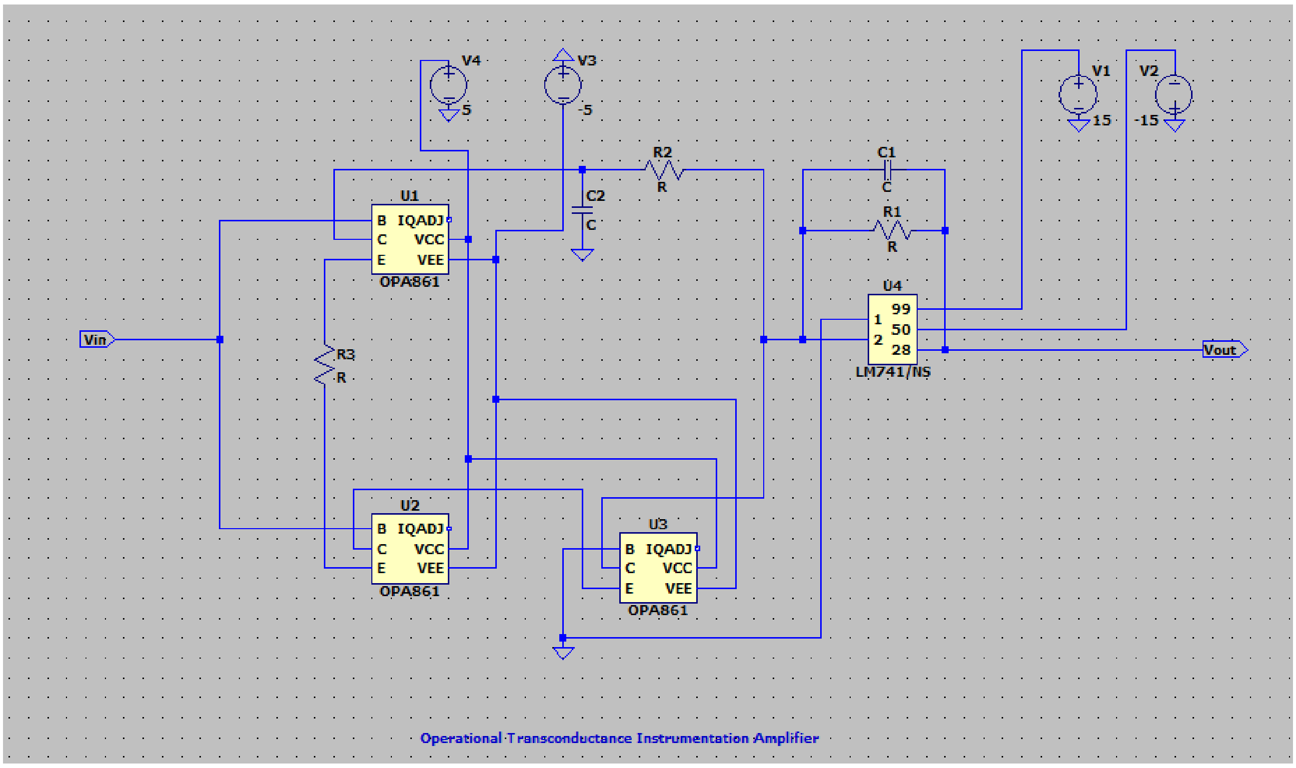
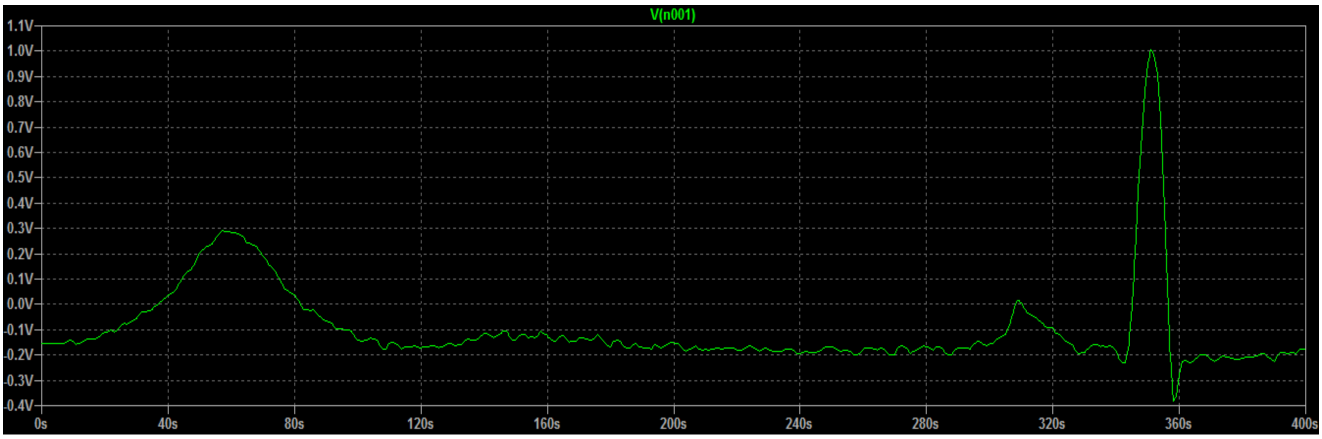


Figure 5.2. OTA Based Instrumentation Amplifier

Simulations

Electrocardiograph (ECG) Bio - potential Signal



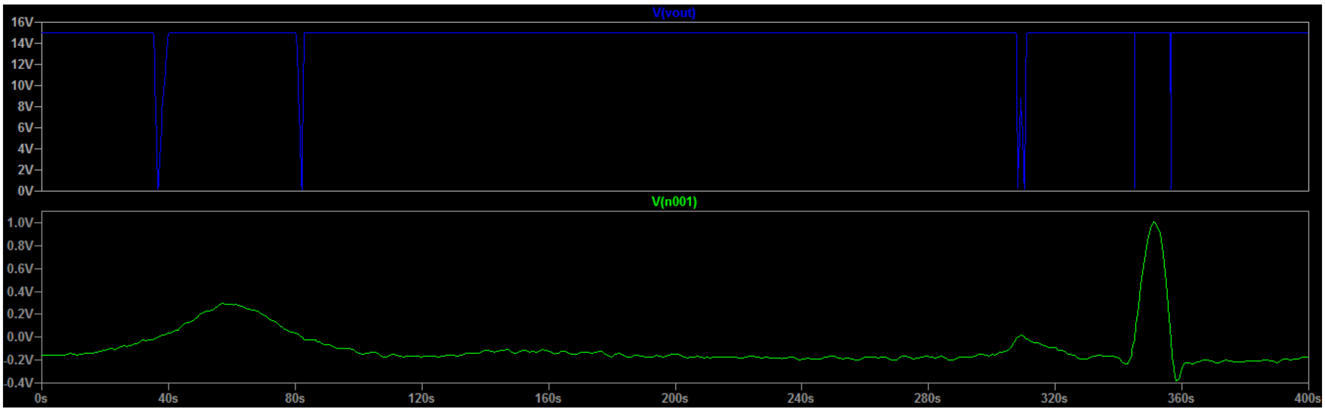


Figure 6.1. Input ECG Signal Source

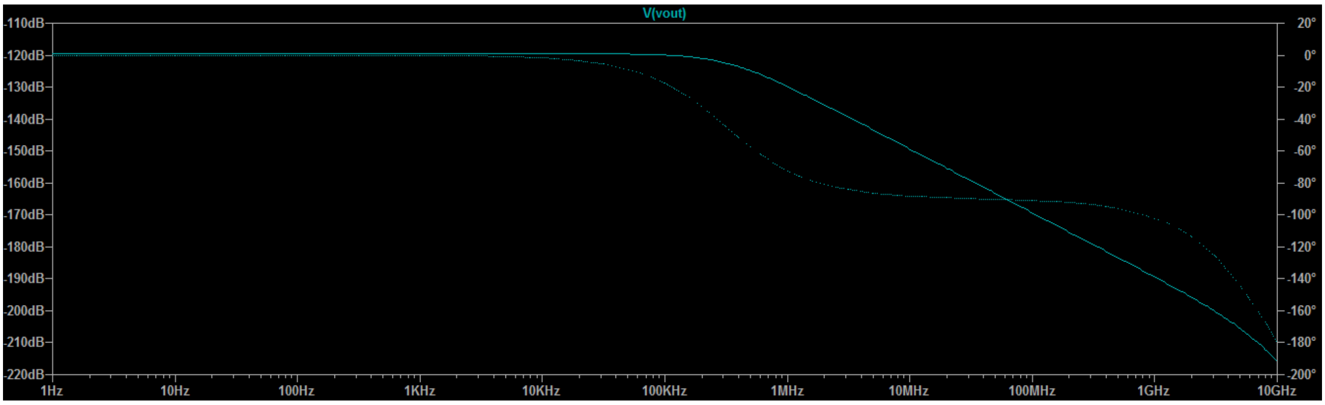


Figure 6.1.1. Frequency Response Curve of OTA Instrumentation Amplifier in Differential Mode Configuration

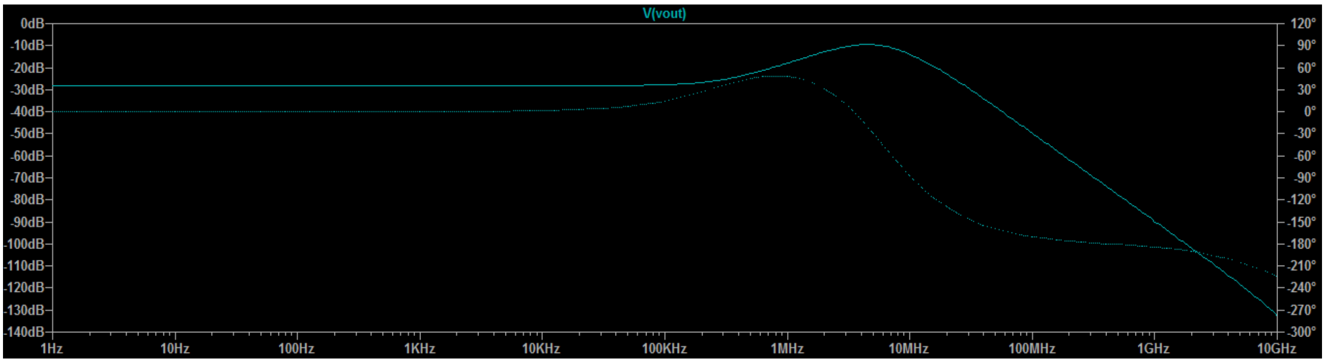
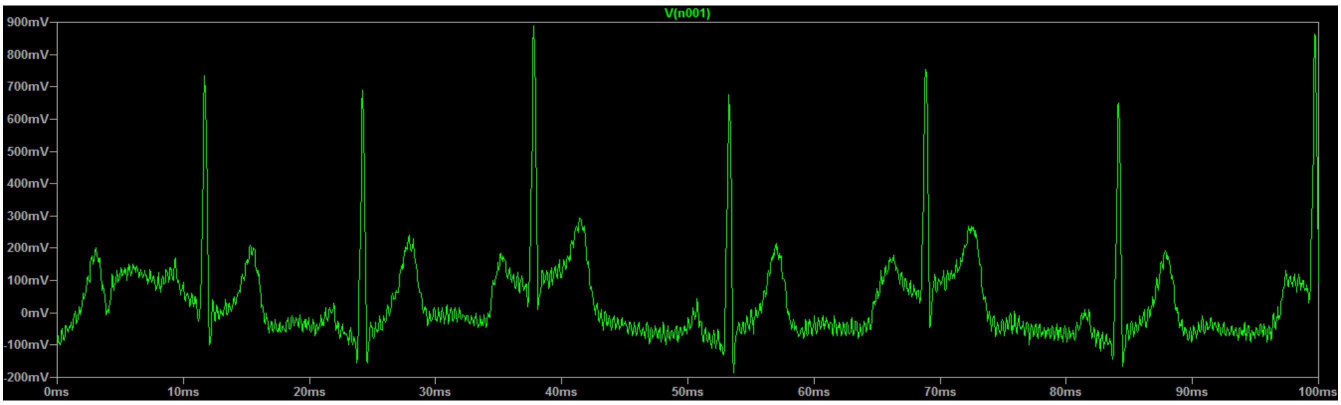


Figure 6.1.2. Frequency Response Curve of OTA Instrumentation Amplifier in Common Mode Configuration

Electroencephalography (EEG) Bio - potential Signal



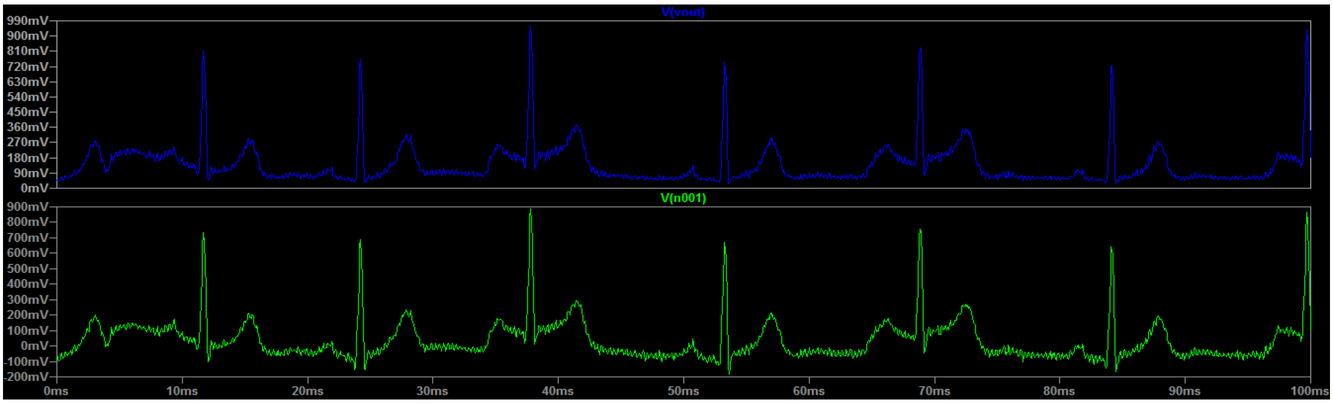


Figure 6.2. EEG Signal Source

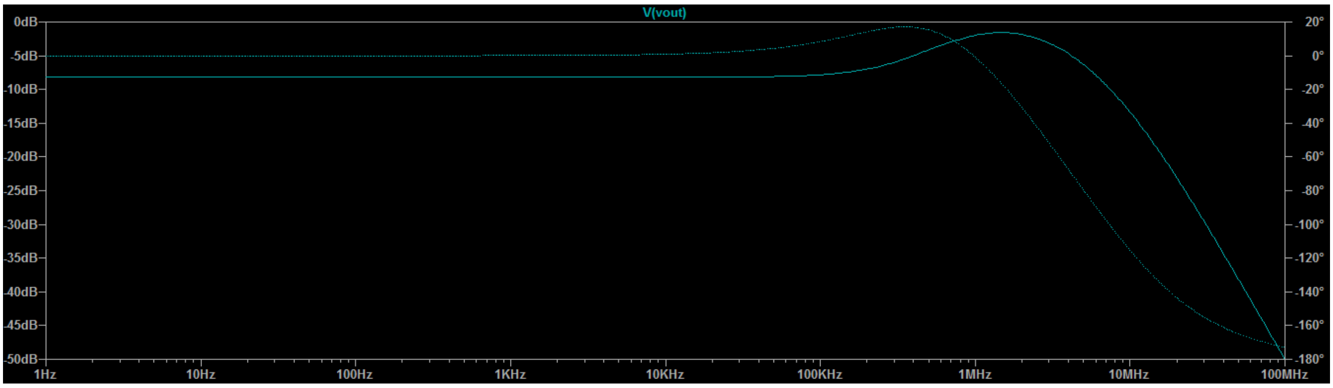


Figure 6.2.1. Phase Response of OTA Instrumentation Amplifier in Common Mode Configuration

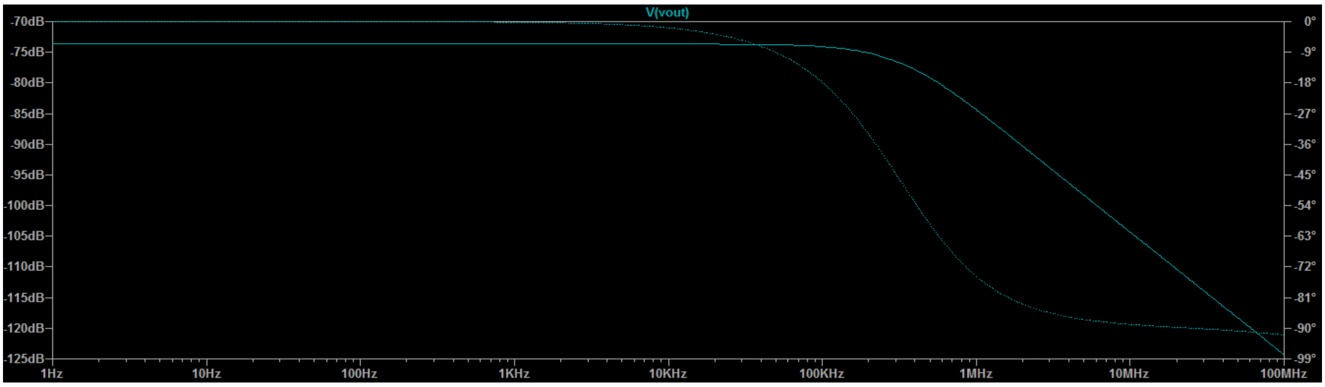
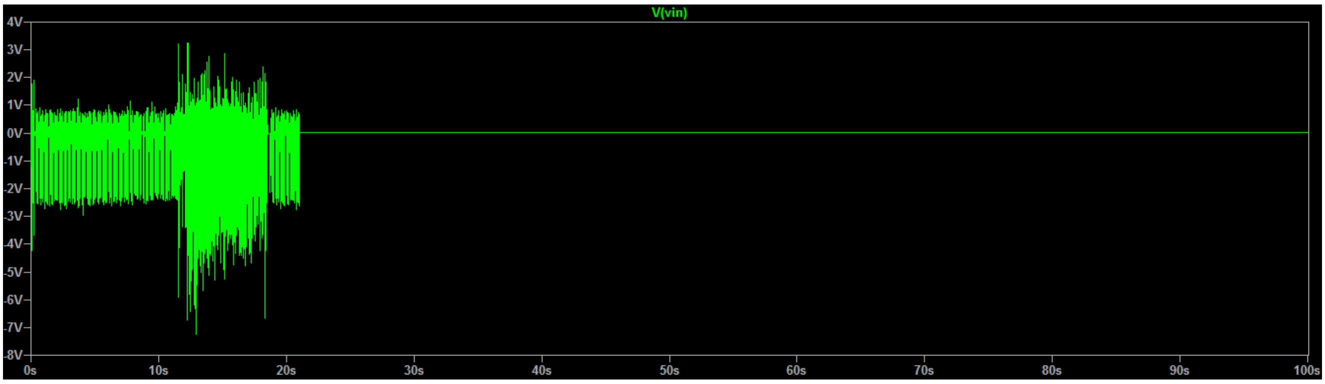


Figure 6.2.2. Frequency Response of OTA Instrumentation Amplifier in Differential Mode Configuration

Electromyography (EMG) Bio - potential Signal



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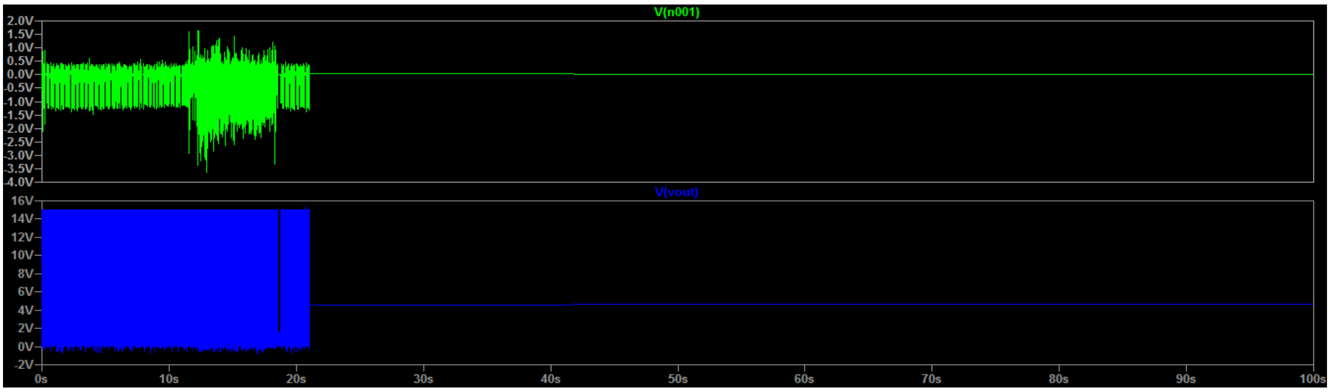

Figure 6.3. Input EMG Signal Source

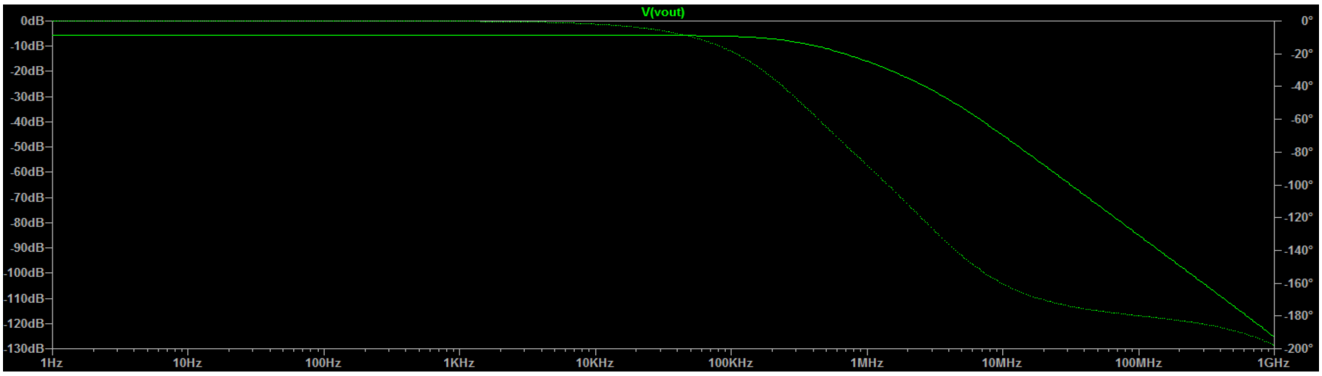

Figure 6.3.1. Frequency Response of OTA Instrumentation Amplifier in Differential Mode Configuration

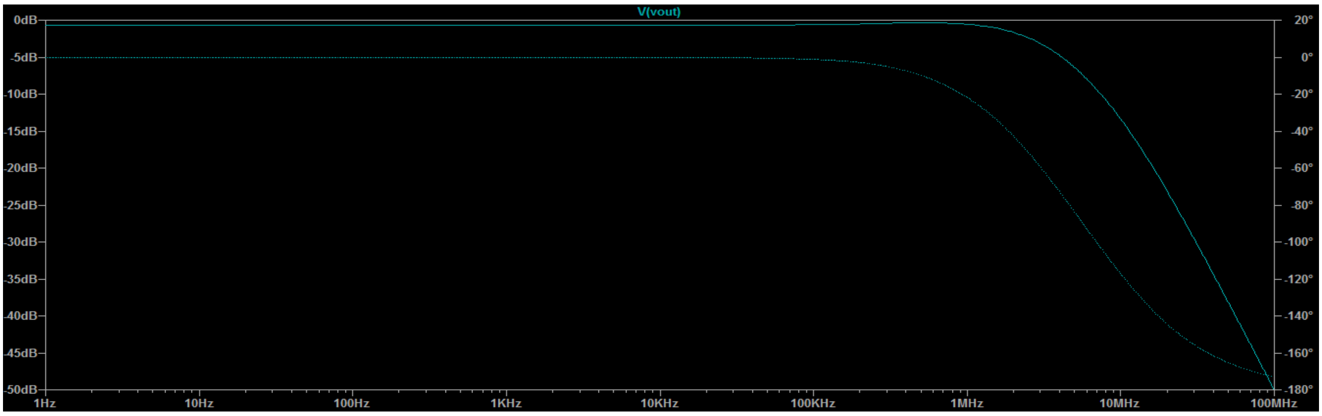

Figure 6.3.2. Frequency Response of OTA Instrumentation Amplifier in Common Mode Configuration

Observation Table

Table 1. Instrumentation Amplifier Parameter Values for Bio-potential Signals

Instrumentation Amplifier Parameters	ECG Bio-potential Values	EEG Bio-potential Values	EMG Bio-potential Values
CMOS Technology	0.13 µm	0.13 µm	0.13 µm
Supply Voltage	1.8 V	1.8 V	1.8 V
Power Consumption	0.09 W	0.09 W	0.09 W
CMRR (DC)	54 db	54 db	54 db
-3 db frequency BW for Differential signals	364.58 KHz	415.447 KHz	217.711 KHz
-3 db frequency BW for Common Mode signals	8.9724 MHz	674.8541 KHz	293.54 MHz

Conclusion

The operational Trans conductance amplifier based instrumentation amplifier has been implemented to analyze EGC, EEG and EMG bio potential signals. An instrumentation amplifier implemented has wideband OTAs with CMRR of value 54 db and slew rate of 900 v/µs with operating bandwidth of 80 MHz The cut off frequency for ECG, EEG and EMG signals are measured as 364.58 KHz, 415.447 KHz and 217.711 KHz respectively. Operational Trans-conductance amplifier based instrumentation is suitable for such bio potentials analysis. Future focus should be emphasis on the improvement on the value of CMRR also circuit the implementation should process complex bio-potential signals such as EEG and EMG bi-potential signals.

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