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PERFORMANCE EVALUATION OF DIFFERENTIAL BIO-POTENTIAL AMPLIFIER

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Abstract-*Differential Bio-potential Amplifier is used to measuring the bio-impedance of the living things, like human body. The value of bio-impedance of body is very low on scale. To enhance it in a readable for this amplifier is used. It increases the value tobio-impedance up to very high on a scale. So measurement of bio-impedance correctly is a difficult task. It requires very precision circuitry to calculate it and enhance it.*

The performance of existing current driving circuits was also analyzed. Measured data showed that they failed to achieve desired specifications as one or the other parameters did not matched according to requirement. This was due to different component gain achievement .Most of these limitations might be reduced as has been done in this research. In applications where highly précised amplifier with high input impedance and CMRR is required, this proposed circuit can be used.

In this research work, we have explained that how the performance parameters and correct choice of components required to meet the high input impedance and CMRR of a circuit. An approach of using TLV2474 op-amp in place of conventionally usedop-amp. In proposed circuit has been shown to have better performance than all other input impedance & CMRR used in past research works. A complete circuit analysis for input impedance and CMRR is performed using MULTISIM software developed by national instruments under wide range of components different-different values.

Key Words:CMRR, Bio potential Amplifier, Input Impedance, Opamp.

1.INTRODUCTION

Bioelectrical impedance measurement is a simple and innocuous way for electrical characterization of cells and tissues. In this, a minor current is injected in the body to measure the voltage developed by it. From there the bio-impedance of the body could be calculated. There are many research work has been done to get the actual value of the voltage and to enhance it to readable form.

The aim of this thesis is to design a differential bio-potential amplifier with high input impedance and the high CMRR (common mode rejection ratio) along with the DC suppression. Bio-potential amplifiers are used where the large CMRR and low noise designs are requires. It also used in differential ADCs .these differential ADCs are widely used for data acquisition and portable applications. As previously mentioned, the main aim of this project has been the study and development of a design of differential bio-potential amplifier. The increased performance of the bio-potential amplifier in terms of input impedance and CMRR are explained in detail. The desired circuit is designed and simulated using Multisim software.

Bio-impedance, bio-electrical, and the electrical properties of tissue are much about the same things. If we apply electricity from an external source outside the living organism under study (exogenic current).we measure bio-impedance, or perform electrotherapy. Bioelectricity is a broader concept, covering also the electric currents associated with thelife processes, and their bio-potentials. Such electricity is called exogenic which means that it is internally generated in the tissue. Many applications are well known related to bio-impedance i.e. ECG and EEG.

Under linear conditions and for the same tissue, unity cell impedance Z, admittance Y =l/Z, complex permittivity ϵ and complex conductivity σ = jε. All contain the same information, but differently presented. Tissue can be characterized as a dielectric or an electrolytic biomaterial and by a relaxation or immittance model. It may be examined withsine, step or other waveform signals. As long as linear conditions prevail, the information gathered was the same. At high voltage and current levels biomaterials are non-linear, and models and parameters must be chosen with care. The interpretation of the measured data was extremely dependent on the angle of view and the choice of model. One of the most fundamental choices to be made is between impedance and admittance, or series and parallel models.

Electrical bio-impedance is defined as the measurement of the electrical impedance of abiological sample. This parameter is of minor importance. However, it can reflect some interesting physiological conditions and events. It is defined three frequency regions for the dielectric properties of biological materials from the observed main dispersions of the conductivity and the permittivity shown in fig. 1.

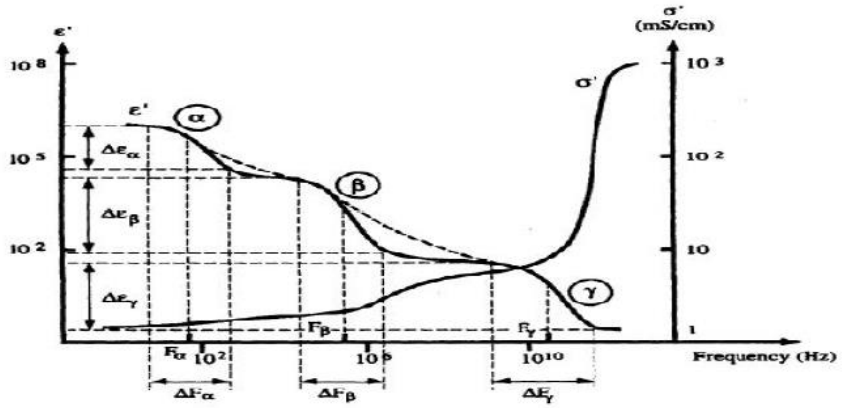

Fig- 1: Three frequency regions for the dielectric properties of biological materials[1]

2. RELATED WORK

AntoniIvorra[2] provided the essential data of circuit theory and also the magnetic attraction associated with bio-impedance field, during this he lined all the essential terms associated with bio-impedance analysis like: cellular measurements, body composition, tissue classification, circuit theory and electrical bio-impedance observance.

Rafael Gonzalez-Ladaeta[5] projected a completely unique technique is projected to live the center rate rather than ancient methodology. It detects the center rate variations by blood circulation within the body. This will be measured by the platform kind electrodes and area interface between the each feet like some rest room weight scale. Advantage of this method is time needed to live the center rate is extremely less additionally it doesn't want any skin preparation, neither any special ability to work this device.

Ursula G. Kyle[8] provides the essential information however the bio-impedance of frame will measured and its principles. There's lack of a regular methodology to calculate BIA(bioelectrical electric resistance analysis) of the frame. It depends on several factors like age, sex, population and weight. During this paper author provided the various equations to calculate the BIA (bioelectrical electric resistance analysis) and calculated error associated with it. However he failed to achieve one standard equation of measuring bio-impedance.

Ørjan G. Martinsen[11] prompt a bio-electrical measuring technique that it is doable to observe fake or "gummy" fingerprints live. Fingerprint is widely used because the biometric, however, 80% of those systems are simply fooled with completely different types of pretend fingers with imprinted patterns. That the author projected a way supported measuring of electrical characteristics of various layers of the skin. Electrode array with three alternative current injecting electrode sets and measured impedance modulusresponse for one live finger & the "gummy" fake finger.

Ramon Pallas-Areny and John G Webster[10] have done an analysis of a differential amplifier using an op-amp and also of a three op-amp instrumentation amplifier (IA) and solved equations for CMRR assuming finite values of differential and common-mode gains. In a three op-amp IA, if the input buffers are not built from a pair of matched op-amps, the CMRR will be limited to a small value.

Mahshid Nasserian[6] achieved a low-power graph (EEG) analog front-end (AFE) with ultra-high input impedance. He designed the circuit in three stages 1) buffer and high pass filter, 2)a non-inverting amplifier 3)differential amplifier. The planned circuit provides excellent high input impedance and CMRR (higher than 110db) with awfully low power consumption .due to these specifications it is utilized in wearable applications.

YuhwaiTseng[4] gave a bio-potential front-end amplifier within which the MOS transistors area unit biased in sub threshold region with a provide voltage and current. It consist of an instrumentation amplifier (IA), a programmable gain amplifier (PGA), and digital control interface.AC-coupling with electrical phenomenon feedback offers the IA a high CMRR and large input impedance.

Spinelli[7] has given the concept of 3 op-amps with active DC suppression.

Instrumentation amplifiers were used in that. That circuit was good in terms of cost and simplicity while maintaining the high CMRR and input impedance.

Fan Zhang[3] projected a plan of a bio-potential audio system. It's principally work on the low power consumption and therefore the low noise occurrence. During this paper, he mentioned the progression of 3 BPA designs: a closed-loop fully-differential telescopic cascade amplifier (BPA1), an open-loop complementary-input (BPA2), and a closed-loop fully-differential complementary-input amplifier(BPA3) that leverages the salient style techniques of the primary two amplifiers[3]. The 3 BPAs exhibit low input-referred integrated noise.

Chun-hsiang Chang[9] projected an idea of use negative capacitance in input stage to enhance the input impedance of the circuit while not degradation of its CMRR. The Instrumentation amplifier (IA) design includes two digitally programmable (8-bit) capacitors between the input stages.

3. DIFFRENTIAL AMPLIFIER AND CMRR

It's difficult task to measure correct impedance of a biological things. This is often owing the fact that over a different- different frequency the impedance of biological material changes and varies so widely. Hence to control it over the frequency range is a very difficult task. In practical way, the measured impedance of a biological material (the ratio of measured voltage to the applied current) is actually a combination of the biological thing's impedance, the electrode/tissue interface impedance and therefore the impedance offered by the drive circuit concerned within the measurement.
Despite of electrode's impedance mismatch, a high input impedance and the CMRR are the very important features for bio-potential amplifiers. This high CMRR and the desirable input impedance can be achieved by using the following aspects-
1. Using differential amplifier at the input stage
2. Not using any ground component at the input stagetime t.
Instrumentation amplifier circuit is shown in fig. 2.

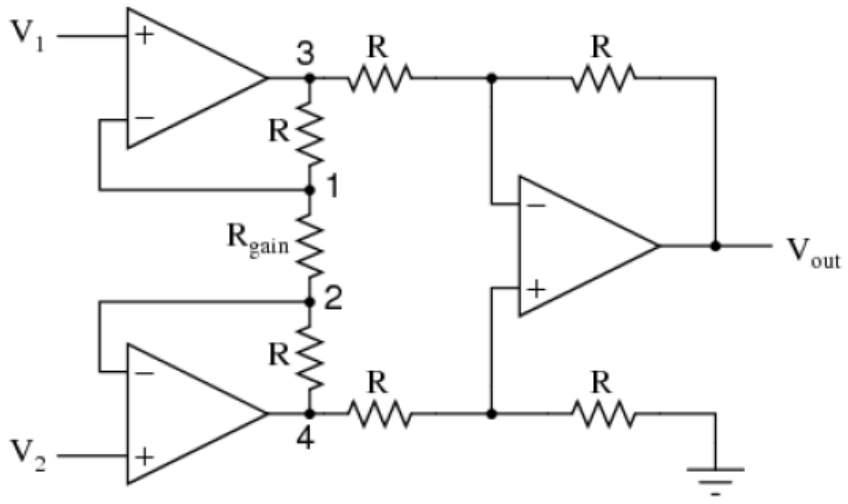

Fig- 2: Three-op-amp instrumentation amplifier with two coupled input

The common-mode rejection ratio (CMRR) of a differential amplifier (or alternative device) measures the ability of the device to reject common-mode signals (especially noise), that present at the same time, with same value and in phase at both the inputs of the amplifier. A perfect differential amplifier would have infinite CMRR, this is often not possible in follow to achieve this much CMRR. A high CMRR is needed when a differential signal be amplified within the presence of a probably massive common-mode input means same input is applied on both the terminal of differential amplifier to reduce the noise signal.
Op-amps, primarily based on differential amplifiers mainly used in instrumentation circuits acting at frequencies less than one hundred kHz. At higher frequencies, discrete transistors are replaced by op-amps, for instance, in oscilloscopes. Differential amplifiers are very important because of their ability to reject power-line and alternative common- mode interference that follows from their high common mode rejection ratio (CMRR).At low frequencies, for the single-op-amp differential amplifier (DA) the employment of a trimming potentiometer is better than the relaying on low-tolerance impedance, owing to the high value of CMRR achieved. There is hard and fast of 90" phase shift for the CMRR at frequencies on top of 1 KHz.For the three-op-amp IA, it's very vital for input buffers to be "coupled" and to be designed from a matched op-amp combine. The most effective CMRR is obtained once the differential gain is focused within the input stage, however in any case it decreases at frequencies on top of one KHz owing to the reduced CMRR for the differential stage at these frequencies[10].

4. PROPOSED BIOPETENTIAL DIFFERENTIAL AMPLIFIER

Bio-signals are basically monitored in the form of potentials, voltages, and electrical field strengths generated by nerves and muscles systems. The measurements include voltages at very low levels, typically ranging from 1 μV to 100 mV, with higher source impedances and superimposed high level of interference signals and noises.
Amplifiers used to measure such type of signals have to satisfy very specific requirements. They have to produce amplification selective to the physiological signal, reject superimposed noisy signal and interference signals, and guarantee protection from

destroying through voltage and current surges for both patient and electronic equipment. Amplifiers offers such features and specifications are known as bio-potential amplifiers.

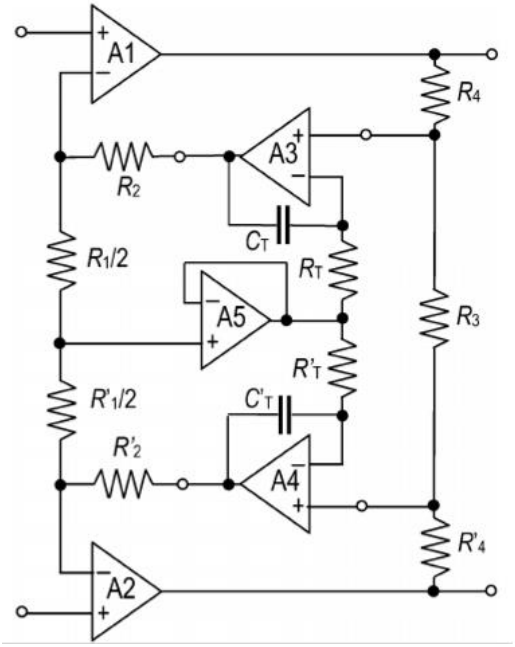

Fig- 3: Bio potential Differential Amplifier [12]

A type of configuration for the measurement of bio-potentials is shown in Fig. 4. Three different electrodes, two of them scans the biological signal and the third providing the reference potential, connect ground signal to the amplifier. The input signal to the bio potential based amplifier consists of five components: (1) the desired body potential, (2) undesired body potentials, (3) a power line interference signal having frequency 50 Hz and its harmonics, (4) interference signals generated by the tissue it means electrode interface, and (5) noise. Proper designing of the amplifier provides rejection of a huge portion of the signal interferences. The main task of the differential amplifier as shown in Fig. 3 is used to reject the line frequency interference that is electrostatically or magnetically coupled into the consideration. The desired bio-potential appears in form of voltage between the two input terminals of the differential amplifier and is referred to as the differential input signal. The line frequency interference signal include only very minute differences in amplitude and phase between the two connecting electrodes, causing approximately the same potential at both input terminals, and thus it appears only between the inputs and ground and is called the common mode signal. Complete rejection of the common mode signal is one of the most important characteristics of a good bio-potential amplifier.

(a)CMRR

The common mode rejection ratio (CMRR) of an amplifier is defined as the ratio of the differential mode gain of amplifier over the common mode gain of amplifier. The rejection of the common mode signal in a bio-potential amplifier is both a function of the amplifier CMRR and the source impedances that is Z1 and Z2. For an ideal bio-potential amplifier with Z1 = Z2 and infinite common mode rejection ratio of the differential amplifier, the output voltage is the pure biological signal amplified by G_d, the differential mode gain: $V_o = G_d V_{di}$. With finite common mode rejection ratio, the common mode signal is not completely rejected, adding the interference term $G_d V_c / CMRR$ to the output signal.

Even in the case of an ideal differential amplifier with infinite common mode rejection ratio, the common mode signal will not completely disappear unless the source impedances are equal. The common mode signal V_c induces currents to flow through Z1 and Z2. The regarding voltage drops generate a difference if the source impedances are not equal, thus generating a differential signal at the amplifier input stage which, of course, is not rejected by the differential amplifier. With amplifier gain G_d and input impedance Z_{in}, the output voltage of the amplifier is:

$$V_o = G_d V_{di} + \frac{G_d V_c}{CMRR} + G_d V_c \left(1 - \frac{Z_{in}}{Z_{in} + Z_1 - Z_2}\right) \quad (1)$$

(b) DC SIGNAL COMPENSATION

Usually, the dc component that is zero frequency is subtracted in a single-ended stage following the dc-coupled front end, whose amplification gain must be limited to middle values to prevent output saturation.

As a result, the common mode rejection ratio is quite limited and the second amplification stage induces to the amplifier equivalent input noise. Furthermore, this type of solution cannot be applied to overall systems with differential analog to digital converters (ADC), which are quite convenient in electronics circuit design consideration. The alternative approach is presented

with a fully differential dc-suppression circuit in fig. 4. It includes a fully differential integrator and also a fully differential feedback model which preserves the balanced structure of the fully differential input amplifier. This approach can be assumed a balanced extension, which is based on the two-op-amp instrumentation amplifier. The proposed circuit inherits its best dc input range and low noise, whereas the CMRR is being independent from passive component mismatch.

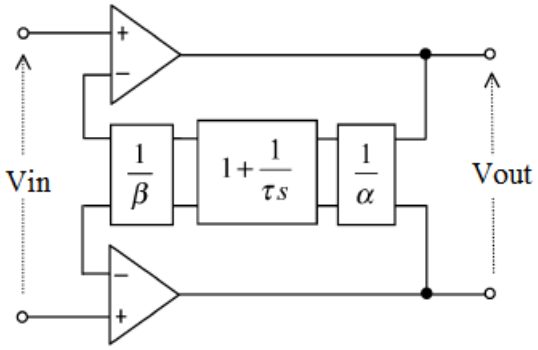

Fig- 4: Fully Differential Circuit for DC Suppression [12]

Considering a negligible error voltage at the input side of op amps, the ratio between differential-mode input and output voltages

$$A(s) = \frac{V_{out}}{V_{in}} = \frac{\alpha\beta sT}{1+sT}$$

Nominal Frequency Gain

$$A_{nom} = \alpha\beta$$

High pass cut-off frequency

$$f_L = \frac{1}{2\pi T}$$

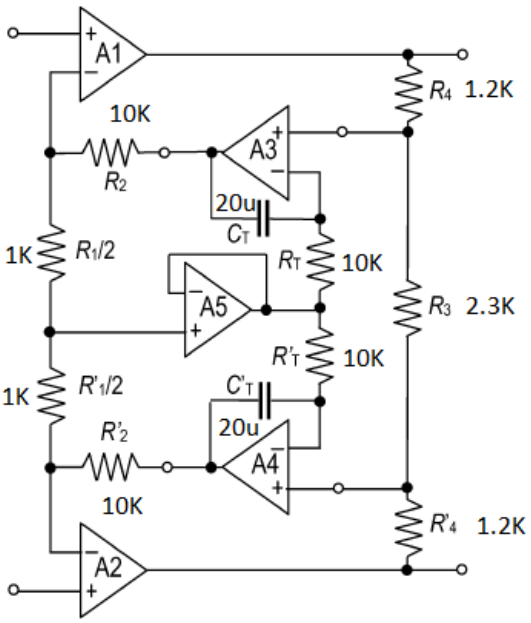

Fig- 5: Implementation of the Proposed System

If initially we assume

$R_1 = \acute{R}_1$

$R_2 = \acute{R}_2$

$R_4 = \acute{R}_4$

$R_T = \acute{R}_T$

$C_T = \acute{C}_T$

We have

$$\alpha = 1 + \frac{2R_4}{R_3}$$

$$\beta = 1 + \frac{2R_2}{R_1}$$

$$T = R_T C_T$$

Assuming peak to peak output op amps and a single power supply, the maximal differential-mode dc-input voltage generates the integrator output reach V_{cc}. Because the integrator output is attenuated by β before being applied to the input, the admissible dc input voltage V_{indc} is

$$V_{indc} = \frac{V_{cc}}{\beta}$$

In this proposed circuit R_T is taken 10Kohm and $C_T$is taken 20uF. In amplification stage $R_2$is taken 2kohm, $R_1/2$ is taken 1kohm, R_3 is taken 2.3kohm and R_4 is taken 1.2kohm.

5.SIMULATION & RESULTS

In the previous circuit R_T is taken 3.3Mohm and $C_T$is taken 20uF. In amplification stage $R_2$is taken 7.5kohm, $R_1/2$ is taken 910ohm, R_3 is taken 2.2kohm and R_4 is taken 56kohm.

Model of biopotential differential amplifier is done on multisim software developed by national instruments. Simulation model is shown in fig. 6.

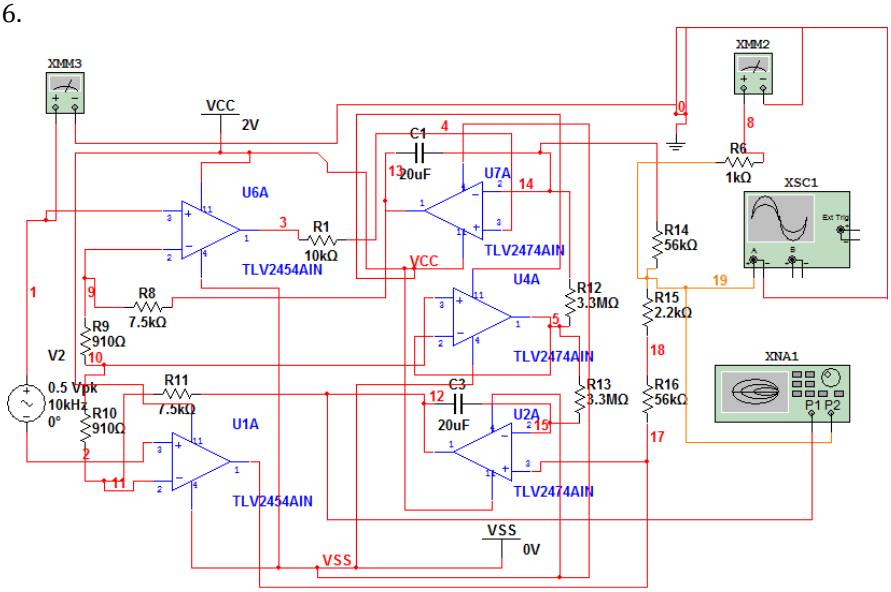

Fig- 6: Simulation Model of Proposed System

In below table Common mode rejection ratio of proposed system and previous model is shown. CMRR values of proposed is better as compared to previous system.

Table- 1:CMRR Comparison for Conventional and Proposed System

Frequency	Previous Model	Proposed System
1Hz	84.30	116.26
10Hz	105.59	156.08
30Hz	124.06	175.16
50Hz	132.88	184.04
75Hz	139.91	191.08

100Hz	144.90	196.08
200Hz	156.94	208.12
400Hz	168.97	220.16
500Hz	172.85	224.04
600Hz	176.02	227.20
800Hz	181.02	232.20
1000Hz	184.89	236.08
10KHz	224.89	275.89
50KHz	252.84	300.21
100Khz	264.85	305.99
300Khz	283.62	309.24
500Khz	291.88	309.74
1MHz	301.51	309.94

CMRR plot for different values of frequency are plotted using MATLAB software. Plot shown in fig. 7 is CMRR for previous model and proposed model. From this figure it can be conclude that proposed system performed better.

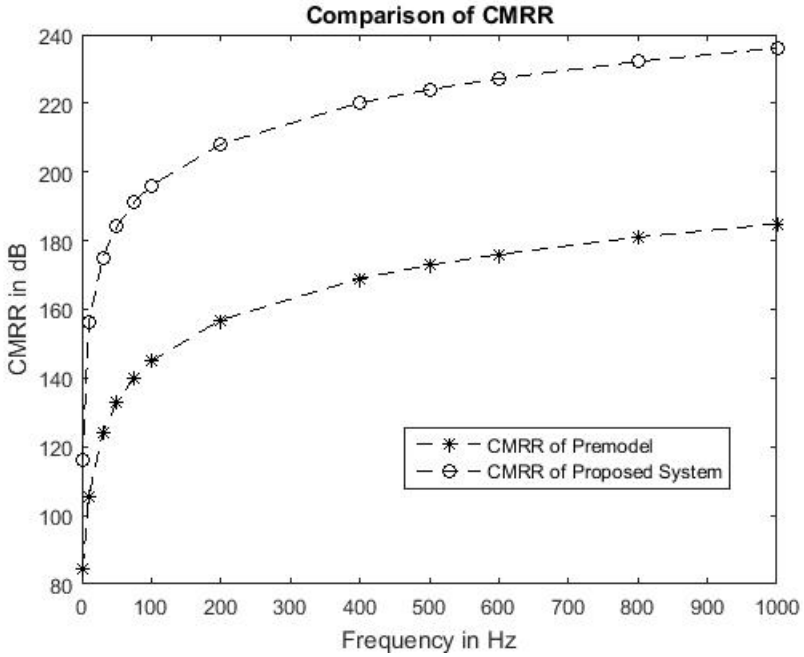

Fig- 7: Comparison of CMRR for Conventional System and Proposed System Model of Proposed System

6. Conclusion

This work has proposed a dc suppression circuit with advance opampthat, in addition to ac coupled system, provides a simple method for efficient removal of the dc level of biopotentials. The proposed circuit is not being include any grounded passive component, which makes the CMRR value of the amplifier very high with tolerance of passive components. Because the proposed simulation model is a typical design with very differential gain for the first amplification stage, the CMRR and voltage noise are optimal.

In this project TLV2474 is used in amplification stage, due to which high CMRR is achieved. At 50Hz frequency CMRR of 184.04dB is obtained, while in previous work 132.88 dB CMRR is obtained at 50 Hz. CMRR obtained.

The TLV2474 included very high gain bandwidth and large signal performance with an ultra-low input side noise voltage (0.23nV/Hz) while using only 25mA supply current. Power saving is critical, but using TLV2474 low power consumption can be achieved.

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