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Second Generation Current Controlled Current Conveyor Based Low Pass Filter Design For The Processing of EEG Signals

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Abstract: EEG signals are noisy signals that allow brain activity to be analyzed. In recent years, it has been seen that current conveyor-based circuits, which have many advantages such as wide bandwidth, high linearity, low power consumption, have been used instead of operational amplifiers in the analysis of these signals. In this study, a second-generation current controlled current conveyor (CCCII+) low pass filter circuit with a cut-off frequency of 100 Hz has been presented for the analysis of EEG signals. The simulation of the circuit was carried out with the Orcad pspice program. In addition, the application circuit of this low-pass filter circuit has been made and oscilloscope images have been obtained for some frequency values. AD844 IC is used as current conveyor in the application circuit. The data of epilepsy patients and normal people taken from the University of Bonn were applied to the CCCII+ low pass filter circuit and the frequency bands of these signals were examined. It has been predicted that if this CCCII+ low pass filter circuit is used in EEG measurements, it will give good results in the diagnosis of neurological diseases such as epilepsy.

Key words: Current conveyor, EEG, Active filter, Pspice.

EEG Sinyallerinin İşlenmesi için İkinci Nesil Akım Kontrollü Akım Taşıyıcı Tabanlı Alçak Geçiren Filtre Tasarımı

Öz: EEG sinyalleri, beyin aktvitesinin analiz edilmesini sağlayan gürültülü sinyallerdir. Son yıllarda, bu sinyallerin analizinde işlemsel yükselteçlerin yerine geniş bant aralığı, yüksek doğrusallık, düşük güç tüketimi gibi birçok avantaj sahip olan akım taşıyıcı tabanlı devrelerin kullanıldığı görülmüştür. Bu çalışmada EEG sinyallerinin analizi için 100 Hz kesim frekansına sahip bir ikinci nesil akım kontrollü akım taşıyıcı (CCCII+) alçak geçiren filtre devresi sunulmuştur. Devrenin benzetimi Orcad pspice programı ile gerçekleştirilmiştir. Ayrıca bu alçak geçiren filtre devresinin uygulama devresi yapılmış ve bazı frekans değerleri için osiloskop görüntüleri elde edilmiştir. Uygulama devresinde akım taşıyıcı olarak AD844 IC kullanılmıştır. CCCII+ alçak geçiren filtre devresine, Bonn Üniversitesinden alınan epilepsi hastası ve normal kişilere ait veriler uygulanmış ve bu sinyallerin frekans bantları incelenmiştir. Bu CCCII+ alçak geçiren filtre devresinin EEG ölçümlerinde kullanılması durumunda epilepsi gibi nörolojik hastalıkların tanısında iyi sonuçlar vereceği öngörülmüştür.

Anahtar kelimeler: Akım taşıyıcı, EEG, Aktif filtre, Pspice.

1. Introduction

Electroencephalography is the recording by the EEG device of electrical signals occurring in nerve cells in the brain tissue with the help of electrodes placed on the skull in case of sleep and wakefulness. The study and imaging of bioelectrical signs obtained as a result of the neural activities of the brain are also called Electroencephalogram (EEG) [1,2]. EEG signals are bioelectrical signals with variable amplitude, phase, and frequencies that are not stationary. While EEG signals have a frequency band range of 0.5-100 Hz, clinical and physiological studies are concentrated between 0.5-30 Hz [1,2]. EEG signals are divided into five sub-frequency bands that indicate certain biological activities [3,4]. Delta (δ, 0.5-4 Hz), theta (θ, 4-8 Hz), alpha (α, 8-14 Hz), beta (β, 14-30 Hz) and gamma (γ,> 30 Hz). These frequency bands are small amplitude signals ranging from 1-400 µV peak to peak.

Analysis of EEG signals has an important place in diagnosing neurological diseases. Various integrated circuits are used for biomedical signals such as EEG signals. These circuits are in many structures, such as OP-AMP based [5], CMOS-based [6], time-frequency based [7], and computer interface based [8]. In this study, a new current-controlled current conveyor (CCCII+) low-pass filter circuit is designed for EEG signals. Current conveyor based circuits have many advantages such as wide bandwidth, wide dynamic range, high linearity, high rate of

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change, low power consumption [9-11]. For this reason, in recent years, several studies such as CCII with CMOS technology, differential differential current conveyor (DDCC) with low voltage and low power capacity, a new electronically adjustable current mode instrumentation amplifier (CMIA), CMOS and differential voltage second generation current conveyors (DVCCII) have been presented to apply to biomedical signals, and thus the interest in current conveyor-based circuits has increased [10, 12-14].

In this study, it is aimed to design a filter circuit with a current conveyor for the analysis of EEG signals. EEG dataset obtained from the University of Bonn was applied to the CCCII+ based low pass filter circuit designed in this study [15]. In this data set, the data sets of A healthy person with epilepsy seizure and E eyes open were used, each of which contained a 23.6-second recording and corresponded to 4097 data points. A low-pass filter circuit with CCCII+ with a cutting frequency of 100 Hz is designed. The Pspice program has been used to simulate this circuit and the Q2N3904 and Q2N3905 BJTs are preferred. An application study of the designed circuit has been made, and AD844 IC, which can show the current conveyor feature, was used in the study, and oscilloscope results were obtained.

2. Second Generation Current-Controlled Current Conveyor (CCCII+)

It was first introduced by Fabre to provide electronic control of the second generation current conveyors. Io are circuits that can be controlled with low biasing current [16]. The CCCII circuit has a 3-pronged structure, X, Y and Z. If the direction of the current flowing from the Z end is towards the circuit, it is called a positive type second generation current controlled current conveyor (CCCII+), and the simulation of the circuit performed with BJTs in the Pspice program is as shown in Figure 1.

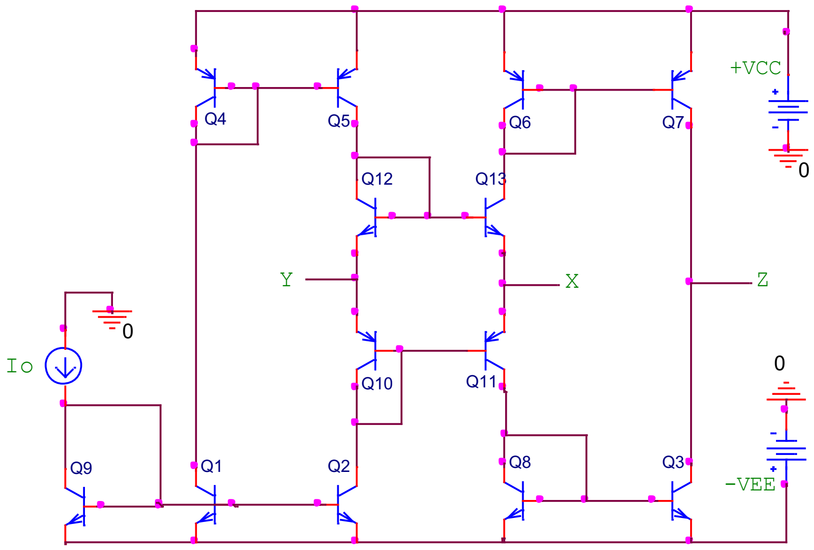

Figure 1. BJT circuit structure of CCCII

The ideal definition relative to the current conveyor circuit in Figure 1 is shown in Equation 1. a, and the equations of the biasing current (I_0) and the (R_X) parasitic resistance, which can be controlled by the polarization current, are shown in the equation 1.b. [17].

$$\begin{bmatrix} I_Y \\ Vx \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & Rx & 0 \\ 0 & \mp 1 & 0 \end{bmatrix} \begin{bmatrix} Vy \\ I_X \\ Vz \end{bmatrix} \quad (1.a)$$

$$I_X = 2I_0 . sinh\ (V_X/V_T) \quad , \quad V_X \ll V_T \quad , \; R_X = \frac{V_T}{2I_0} \quad (1.b)$$

The parasitic resistance R_X varies depending on the bias current I_0 and thermal voltage V_T. The approximate value of the thermal voltage V_T at room temperature is considered to be 25.85 mV. In order to avoid inaccuracies in frequency responses, the R_X resistance should be taken into account.

AD844 IC was used as the CCCII+ circuit in the application circuit. The AD844 Integrated Circuit [18] has been put on the market as a circuit that can show a current conveyor property. Thus, a current conveyor-based circuit whose simulation is performed can be put into practice and results can be obtained. The implementation of the CCII+ circuit with AD844 is shown in Figure 2. In addition, the CCCII circuit can be designed with AD844 integrated by replacing the resistance located at the x end of the CCII circuit with a parasitic resistance that can be controlled by bias current.

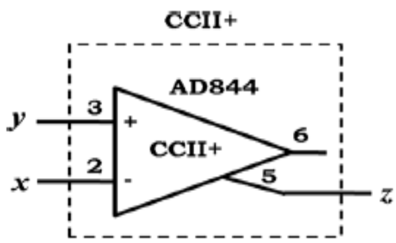

Figure 2. CCII+ implementation using AD844 [19]

3. Simulation Circuit of Low pass filter designed with CCCII+

Low-pass filters are filters that pass signals up to the specified cut-off frequency. The circuit diagram of the voltage mode low-pass filter designed with a second-generation current-controlled current conveyor is given in Figure 3 [20].

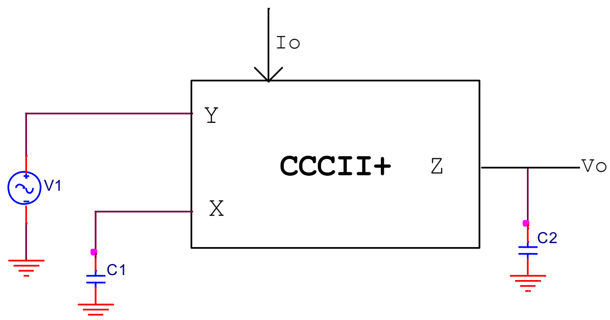

Figure 3. CCCII+ low pass filter circuit diagram

In this circuit diagram, 2 capacitors, one of which is grounded at the X and Z terminals, are used and R_x parasitic resistance is used. The relations between the output and input voltages of the circuit and the cut-off frequency relations of the circuit are given below.

$$\frac{V_{out}}{V_{in}}(s)=\frac{1}{1+sR_xC} \tag{2}$$

$$f_c=\frac{1}{2\pi R_x}\sqrt{\frac{1}{C_1C_2}} \tag{3}$$

In Figure 4, the simulation circuit of the CCCII+ low-pass filter with a cut-off frequency of 100 Hz, designed with Q2N3904 and Q2N3905 type BJT in the Pspice program, is given.

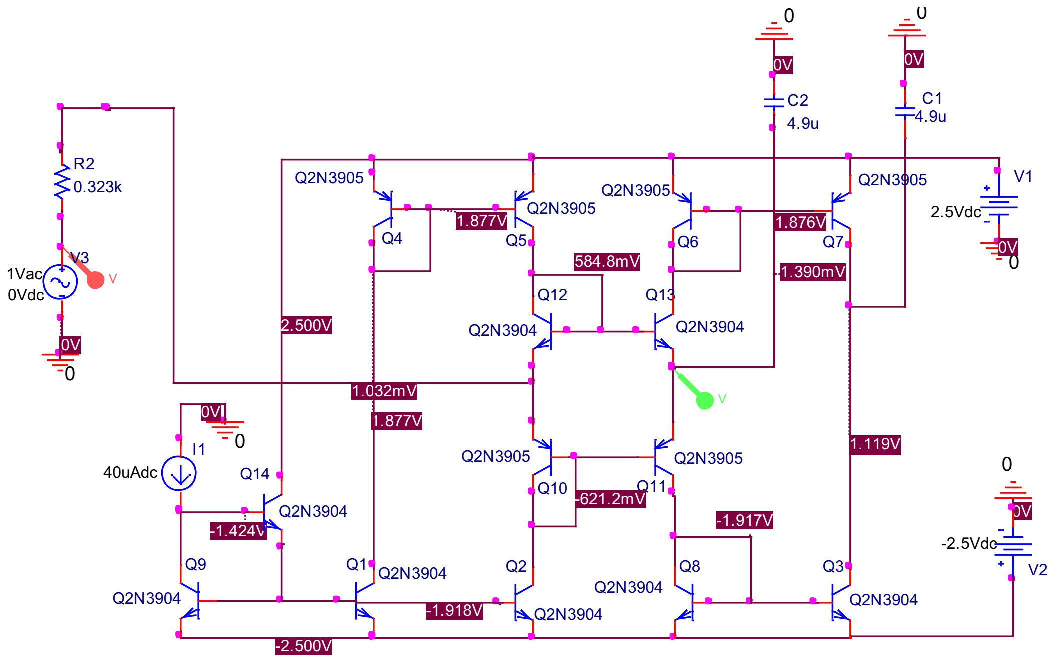

Figure 4. CCCII+ low-pass filter simulation circuit

In the designed circuit, the value of the capacities connected to the X and Z terminals was selected as 4.9μF. The bias current of the circuit is 40μA and accordingly the value of the parasitic resistance is approximately 323Ω. The frequency gain graph of the CCCII+ low-pass filter is given in Figure 5.

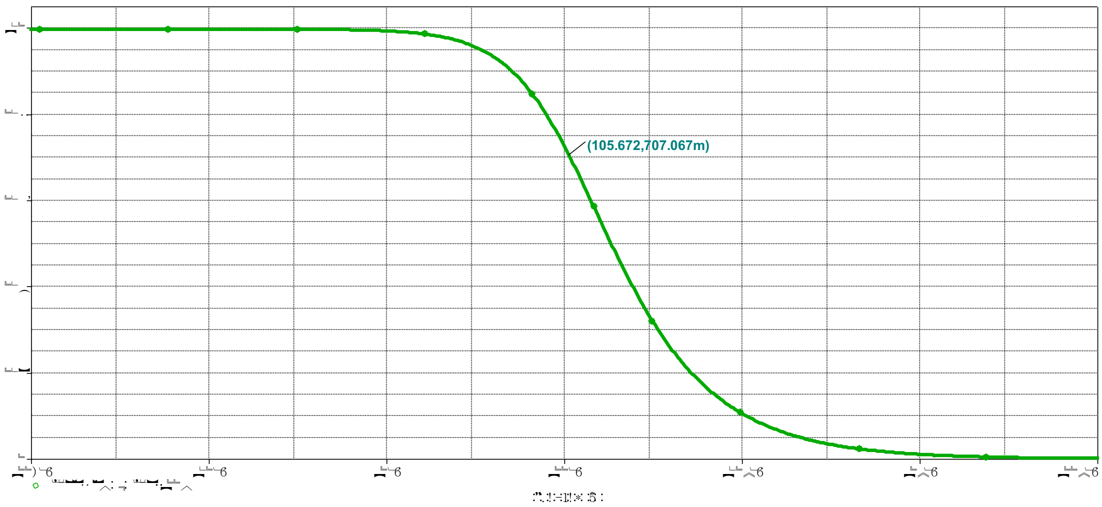

Figure 5. CCCII+ frequency gain graph of low pass filter

While the cut-off frequency of the filter was found to be 100.56 Hz according to the calculations, the cut-off frequency measured according to the frequency gain graph we obtained in Pspice was found to be 105.67 Hz. The maximum frequency gain of the filter is 1.

4. Experimental Results

The CCCII+ low-pass filter circuit simulated in the Pspice program has been applied in the laboratory environment and real-time results have been obtained. A general view of the application study is given in Figure 6.

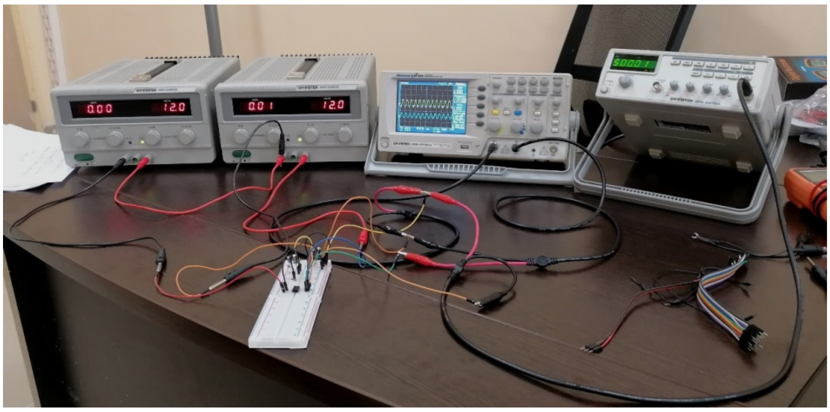

Figure 6. A general view of the application work

In Figure 7, the application circuit of the CCCII+ low-pass filter designed with AD844 integrated into the breadboard is given.

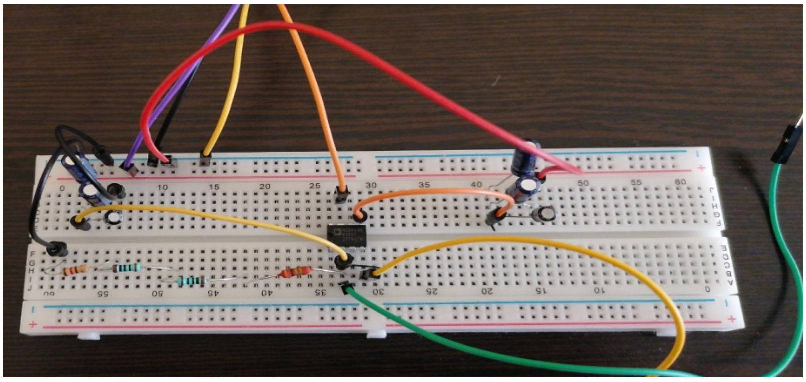

Figure7. Application circuit of the CCCII+ low-pass filter

The oscilloscope images of the low-pass filter designed with CCCII+ are as given in Figures 8, 9, and 10.

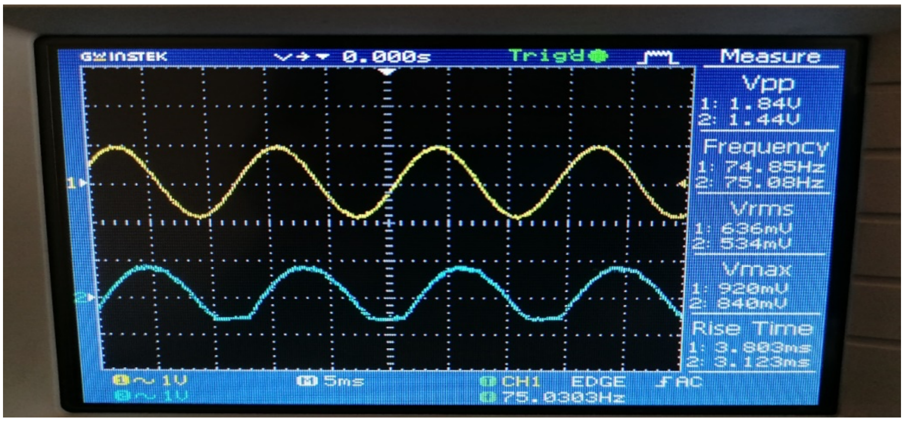

Figure 8. Low-pass filter designed with CCCII+ image at 75 Hz

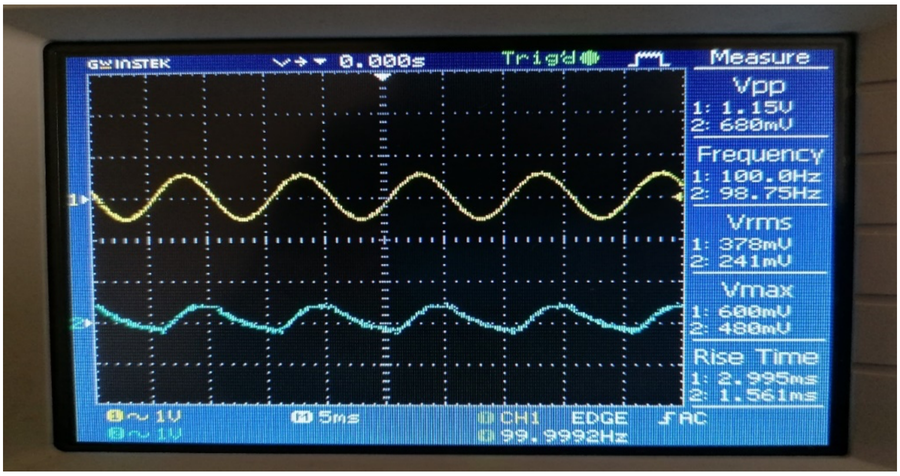

Figure 9. Low-pass filter designed with CCCII+ image at 100 Hz

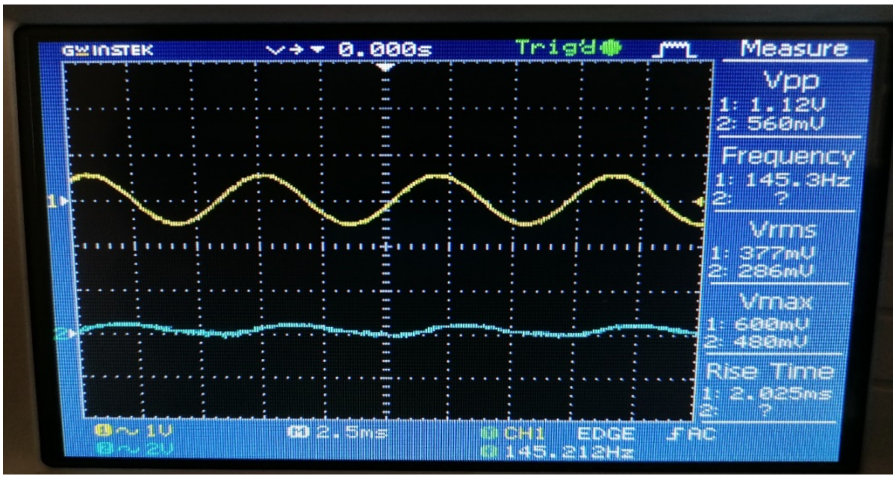

Figure 10. Low-pass filter designed with CCCII+ image at 145 Hz

CCCII+ low-pass filter circuit designed as 100 Hz cut-off frequency is designed with AD844 integrated. The results of the cut-off frequency of the filter circuit at the lower and upper-frequency values were taken and it was seen that the designed filter also cuts off after 98 Hz. It has been determined that the designed filter has good filtering.

5. Conclusion and Discussion

In this study, it is aimed to show the effects of the current conveyor filter circuit for EEG signals by designing a current conveyor (CCCII+) low-pass filter circuit. Here, the low-pass filter is designed for a cut-off frequency of 100 Hz. EEG signals of both epilepsy patients and healthy people were given to the low-pass filter input designed in this study, and the results were examined in a Pspice environment. The input signals of the epilepsy patient and healthy person obtained are as follows (Please see Fig.11, and Fig.12):

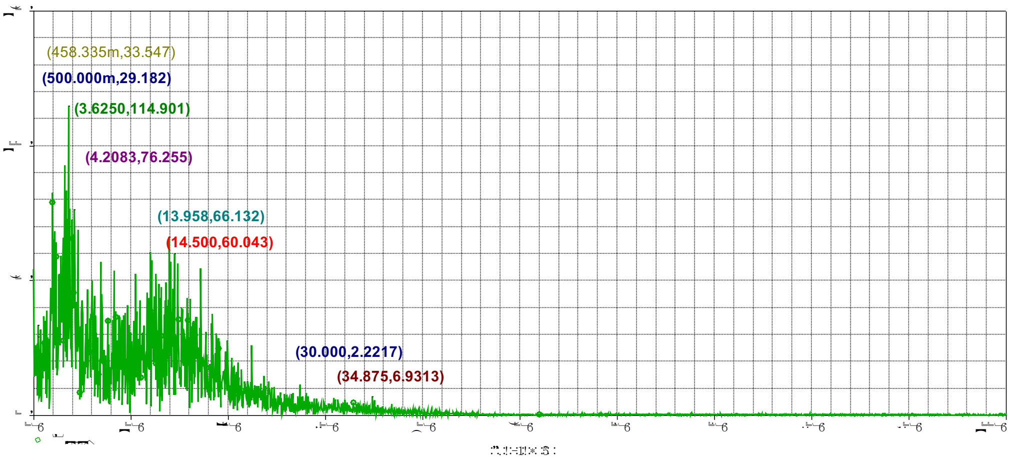

Figure 11. Epilepsy input signal

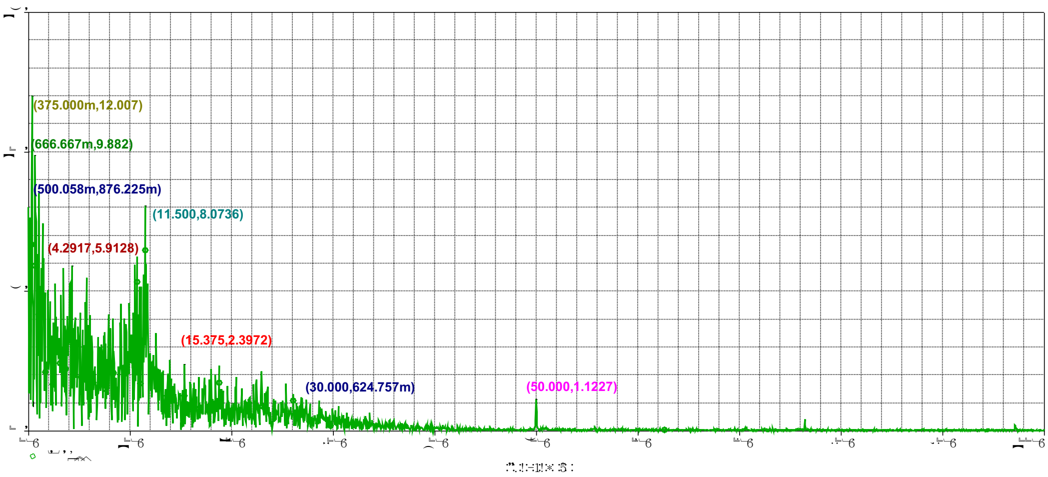

Figure 12. Healthy input signal

The output signal of a healthy person with epilepsy, obtained as a result of Fourier analysis and CCCII+ low-pass filter application, is given below (Please see Fig.13, and Fig.14):

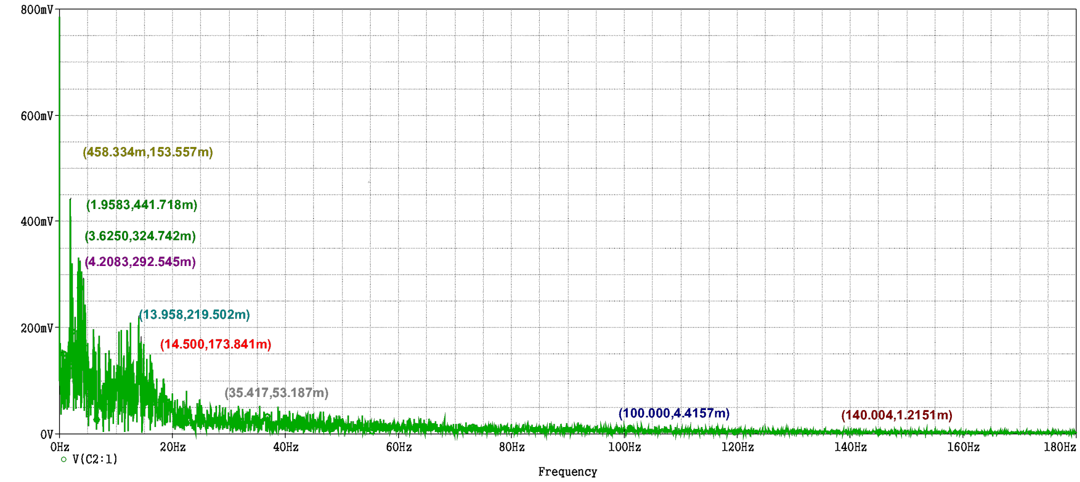

Figure 13. CCCII+ low-pass filter-output signal of an epilepsy patient

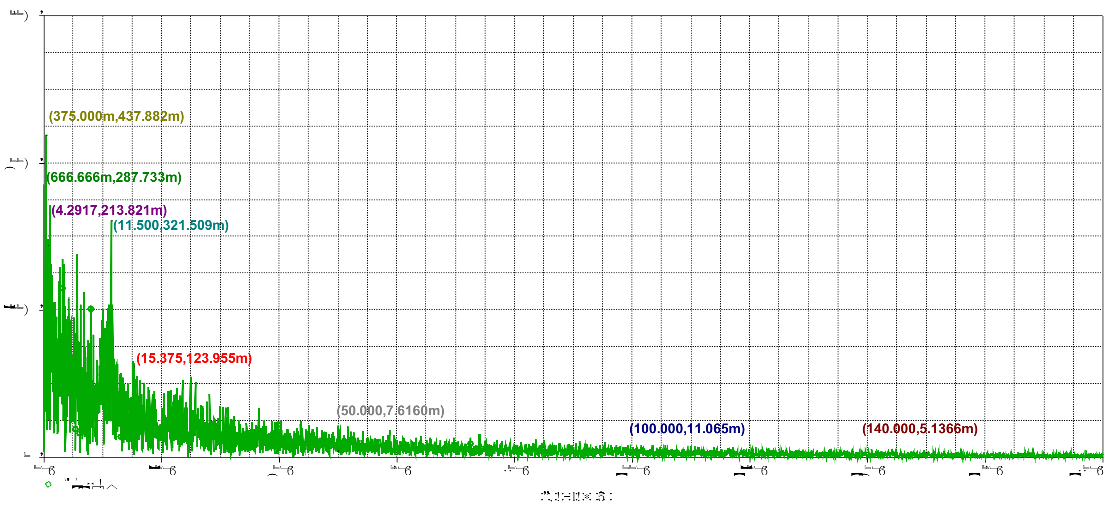

Figure 14. CCCII+ low-pass filter-output signal of a healthy person

Fourier analysis was applied to the signals obtained as a result of the application of the low-pass filter to the epileptic patient and the healthy person, and the changes in the EEG waves were examined. The frequency gain response of current conveyor circuits is very good. In addition, the common-mode signal rejection ratio (CMRR) is important in the high-order common-mode signal rejection process. Since this ratio is quite high in the current conveyor circuit structure, the rejection process can be done easily in the current conveyor circuit.

In this paper aims to see the results of a CCCII+ based low pass filter for a biomedical signal. The results were obtained both with the Pspice program and as an oscilloscope image. When the input signals of the epilepsy patient and the healthy person are examined, it is seen that the amplitude values of the epileptic patient are higher than the healthy person. When a 100 Hz CCCII+ low-pass filter is applied, it is seen that a healthy person with epilepsy filters well when examined for each wave in the EEG signal. The results were obtained according to the oscilloscope images of the CCCII+ low pass filter circuit obtained at different frequencies and by applying the data of epilepsy and healthy people to the simulation circuit. The rate of change in EEG waves, frequency response and the change of output signals were examined. According to the results obtained, we have seen that the CCCII+ circuit performs a better filtering process compared to operational amplifiers. This designed filter circuit will be used in EEG measurements, and it is predicted that the CCCII+ filter circuit will give better results in the diagnosis of diseases such as epilepsy.

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