International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Design of an Electro Encephalo Gram Module and Processing the signals through Savitzky –Golay filter for Machine Learning Applications

Sandhya Kumari Golla[1], Dr. Suman Maloji [2]

Submitted: 08/09/2022 **Accepted:** 23/12/2022

Abstract: Electroencephalography, Magneto Encephalo Graphy (MEG), and Positron Emission Tomography (PET), and also functional Magnetic Resonance Imaging (fMRI), are noninvasive neurosignal recording techniques. Epilepsy is the world's second most prevalent psychosomatic illness, affecting around 40 million people globally. The methodology includes the implementation of an Electroencephalogram(EEG)module that captures the brain signals to analyze the different emotions of a person. The elements of a circuit that use frequency modulation to improve signal-to-noise communications and it has been developed using proteus software and generated 3d module of the same. The Sallen-Key low pass filter is the most often used second-order active low pass filter because of its high input impedance, strong stability, and low output impedance. The proposed method comprises a protection circuit, an instrumentation amplifier, and a Sallen-key circuit that can increase the efficiency of signal to noise ratio. The retrieved signal is fed into the methodological circuit, with the resulting EEG signal being processed using the Savitzky Golay filter. The filtered output was then used to prepare a dataset that could be used for machine learning techniques.

Keywords: *EEG, Instrumentation amplifier, Sallen-Key low pass filter, Savitzky Golay filter, Machine learning techniques.*

1.Introduction

Epilepsy is a serotonin imbalance that affects people of all ages and would be a chronic non-communicable disease. A seizure generated by aberrant neuronal firing is called an epileptic seizure, as contrast to a non-epileptic event like a psychogenic seizure. Epilepsy affects approximately 80% of the people in low- and middle-income nations. It is estimated that nearly to 70% of people with epilepsy might live seizure-free if properly diagnosed and treated. Epilepsy is a term for recurrent, unprovoked seizures. There are several causes of epilepsy, one of which reflects underlying brain dysfunction. Sergi Consul-Pacareu1 and collaborators suggested an alternative 'DRL-less' AFE design and created a small, low-power, wireless, and rechargeable batteries wearable EEG device (NeuroMonitor). Due to interrelationship of channels, this DRL circuit layout confines modularity and adaptability for EEG channels, as the number of channels in the system must be chosen at design time for optmal performance. Hanh Phuc Nong et al. proposed a block diagram of the device control system through brain waves. This module extracts the command code from the recognition module, creates an infrared signal, and delivers it to the appropriate source to switch on and off the TV. In terms of hardware, the system utilizes the Emotiv Epoc+ hat to acquire EEG data, which would be then sent to the PC for network training and to the Raspberry Pi for identification. The CNN network would be used by the software installed on the microcontroller to analyze the patient's thoughts and communicate the command code to the actuator to turn on and off the lights and television. Yuge Sun et al. proposed a high-performance EEG signal amplifier that incorporates a differential amplifier circuit, driven-right-leg circuit, and pre-amplifying components to denoise common-mode interference signals.Lajos Losonczi et al. developed an intelligent EEG model that supports a qualitative conditioner circuit of recorded biosignals, an analog-digital converter, a central processing unit, and a wireless data transmission module. Each of these components is included within the electrode capsule. There have been ten separate operational components in this intelligent electrode. Giovanni Vecchiato et al. tested a sample of healthy people, researchers tested the viability of today's high EEG statistical techniques in the temporal and

[1]*Research scholar, Department of Electronics and communication Engineering,* Koneru Lakshmaiah Education Foundation, *Vijayawada, A.P,INDIA*
[2]*Professor Department of Electronics and communication Engineering, Koneru Lakshmaiah Education Foundation, Vijayawada, A.P,INDIA*
** Corresponding author's Email: sandhyakumarigolla@gmail.com, suman.maloji@kluniversity.in*

frequency domains to monitor brain activity during witnessing commercials, political spots, and PSAs. While watching a commercial video clip in a group of 13 healthy persons, they investigated at the statistical significance cortex spectral energy activity in different frequency bands.

2.Proposed work

The methodology consists of acquiring the signals from the patient through the protection circuit [1].The protection circuit also can be referred as Radio frequency interference. Radio frequency interference is the transmission or dispersion of electrical noise or radio frequency energy produced by electrical and electronic equipment (RFI). This has an adverse influence on nearby equipment or equipment that would be connected to the same electricity grid.The resultant output connected to the Instrumentation amplifier which is extensively used in industrial testing and measurement. The instrumentation amplifier's low drift voltage, great Common mode rejection (Common mode rejection ratio), higher operating resistance, high gain, and other attributes are very beneficial. The output was then fed into a Sallen-key low pass filter, a second-order active filter configuration that could have been used to achieve larger filter circuits such low-pass, high-pass, and band-pass filters (BPF). Figure.1 represents the module of the proposed architecture.

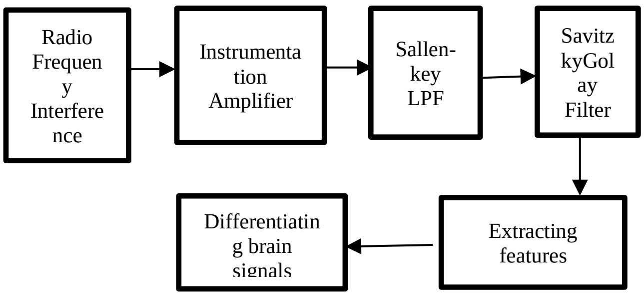

Fig. 1. Module of proposed Architecture

3.Results and Discussion

3.1 Radio Frequency Interference

RF interference is defined as the influence of undesired RF energy in a system, represented as poor performance, data loss, equipment damage, and so on. RF interference is narrowband interference which impacts an electronic system and is considered an (ElectroMagneticInterference) EMI subsystem. There are some types of radio frequency disturbances such as unintentional RF noises, Intentional RF noises, Man-made RF noises. The unintentional RF is the energy radiated or leaked by a device that develops RF energy for utilization within the device.Intentional RF noises are generated by and emitted by devices intentional RF noise. Man-made RF noises are emitted by gadgets such as power electronics, LEDs, computer clocks, and so on. These RF emissions are either deliberate or undesired.In this project,the designed module is the combination of Instrumentation amplifier using proteus software and generated 3d module of the same.Optimization techniques such as deploying RFI filters at the electronic equipment's input minimize incoming interference while somehow preventing it from affecting the electrical power systems via the power code[11][12]. Figure. 2 represents the printed Circuit Board Layout of protection circuit with Instrumentation amplifier. Figure. 3 represents the 3D Module of protection circuit with Instrumentation amplifier.

3.2. Instrumentation Amplifier

The INA122 is a minimal differential signal acquisition precision instrumentation amplifier. Its two-op-amp design provides excellent achievement and utilizing small energy, making it a perfect for portable equipment and data collection process systems[2]. It could possibly have come from such a number of sources. The supply commonmode range has recently been extended to 0.1V below negative rail due to an input level-shift network (single supply ground). With only one external resistor, gain may well be changed from 5V/V to 10000V/V. Low offset voltage (maximum 250V), offset voltage drift (3V/°C), and robust common-mode rejection all are characteristics of laser trimming.The only benefits of employing two opamps to make an instrumentation amplifier are the lower cost and enhanced CMRR. The INA122 can be powered by a single +2.2V source. Throughout the +36V power distribution range, performance is acceptable. Considering its constant supply (up to 200mV from the supply rails), the INA122 contains a steady quiescent current (60A). To maintain load impedances extremely strong throughout the design, battery management usually involves rigorous regulation of vitality consumption.

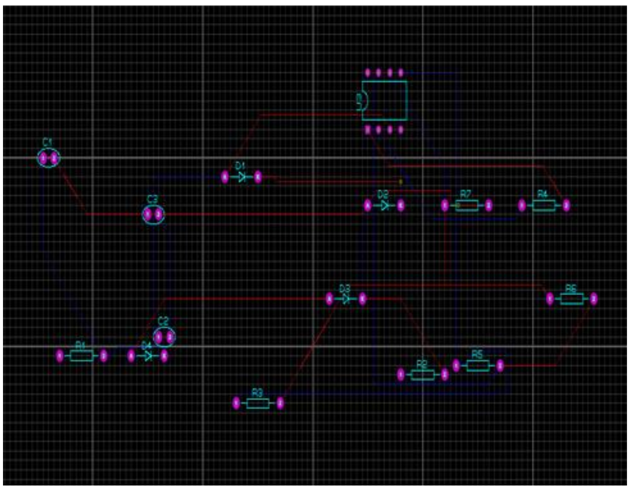

Fig. 2. Printed Circuit Board Layout of protection circuit with Instrumentation amplifier

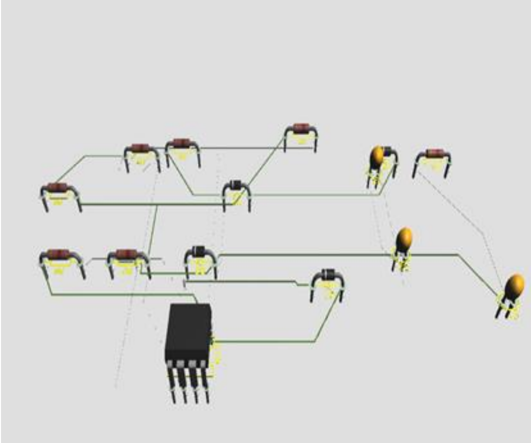

Fig. 3. 3D Module of protection circuit with Instrumentation amplifier

3.3. Sallen-Key Low pass filter

The Sallen-Key topology is a voltage-controlled voltage-source (VCVS) design having high power density, low output impedance, and excellent reproducibility, focused on a personal non-inverting operational amplifier and two resistors.It's a two-stage RC network that serves as a second-order low-pass filter automaticlly.Sallen-Key Filter designs have always had the merit of being easily understandable and implement[3][4]. The application of equal resistor and capacitor values is a good illustration of the Sallen–Key architecture. A Sallen–Key notch filter would be constructed similarly, though it has major limitations. Due to various component interaction, the frequency range, or notch frequency, cannot be enhanced.At low frequencies, the signal is effectively routed to the output, with C1 and C2 acting as open circuits[8]. The data is leaked to ground at the amplifier's input at high frequencies, the amplifier amplifies the inputs to its outputs at a lower frequency, and the signal at Vo[5][6][7] is nonexistent. Positive responses through C2 facilitate signal Q expansion at the cut-off frequency when C1 and C2 have same impedance as R1 and R2..Figure.4 represents the Printed Circuit Board Layout of Sallen-key LPF and Figure.5 represents 3D Module of Sallen-Key LPF.

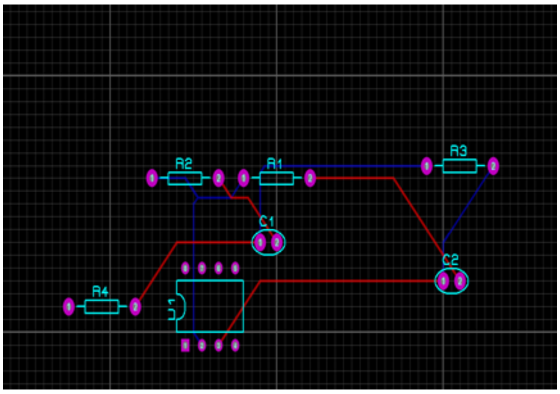

Fig. 4. Printed Circuit Board Layout of Sallen-key LPF

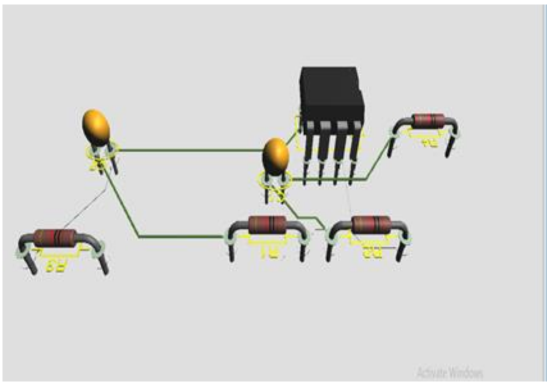

Fig. 5. 3D Module of Sallen-key LPF

3.4 Savitzky-golay filter

The Savitzky-Golay (SG) smoothing and differentiation filter has proven to be a reliable, simple, and effective approach of noise reduction. Smoothing filters, such as Savitzky-Golay, are often used to smooth a noisy signal with a broad frequency range (without noise).Least-squares smoothing filters or digital smoothing polynomial filters are some other names for them. Savitzky-Golay filters sometimes can outperformed traditional averaging FIR filters, which prefer to filter high-frequency signals combined with noise[9][10]. Figure (3) reflects the output of the Savitzky-Golay filter, which can filter the signal without affecting the data's significant data Savitzky-Golay filters preserve high-frequency signal components, but background noise is less effective. Savitzky-Golay filters are the optimum for fitting a polynomial to noisy data frames when they minimise the least-squares error. Table(1) represents the parameters of the sallen-key filter and Table(2) represents the specalizations of the sallen-key filter.

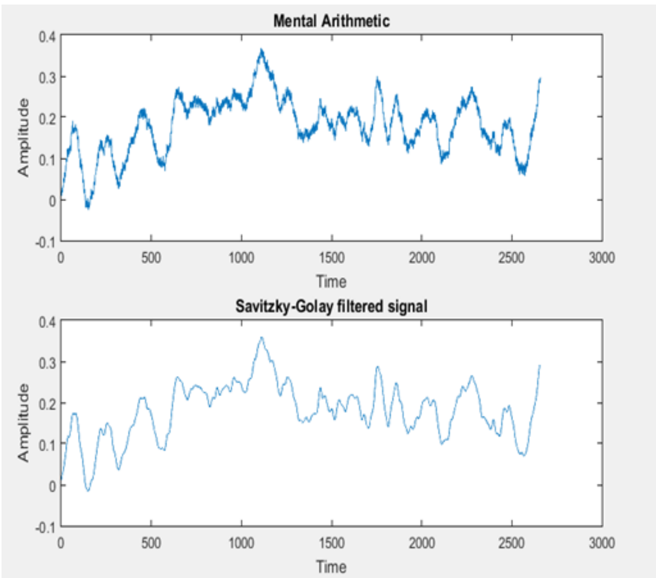

Fig. 6. Mental arithmetic signal of Savitzky-Golay filter.

Table 1. Parameters of sallen-key lpf

S.NO	PARAMETER	PROPERTY
1	Structural design	Op-amp & RC-components
2	Op-amp	To overcome the property of RC
3	Stability	Good stability
4	Performance	High Performance

Table 2. Specalizations of sallen-key lpf

S.NO	PARAMETER	PROPERTY
1.	Voltage gain (A_v)	$1+\frac{R_4}{R_3}$
2.	Cutoff frequency (f_c)	$\frac{1}{2\Pi\sqrt{R1R2C1C2}}$

The received output compared to other wavelet-based methods, including such wavelet decomposition algorithms, the EEG signal was thoroughly filtered with the Savitzky-Golay filter, and the mean value of the EEG signal was not adversely impacted, and is one of the major benefits of this filter.

4.Conclusion

The EEG modulewas designed with the components like Radio frequency interference, instrumentation amplifier, Sallen-key low pass filter, and Savitzky-Golay filter which is an alternative to a higher order low pass filter . This project goal is to lower the amount of circuit blocks in order to keep the module scalable. The output EEG signal of the Savitzky-Golay filter can also be used to extract signal coefficients for machine learning approaches, and is one of the most useful applications for categorizing brain signals.

5. Conflict of Interest

There have been no conflicts of interest from among authors. All co-authors have evaluated and approved the manuscript's content. We ensure that the submission is authentic and has not been reviewed by another publisher.

6. Author Contributions

The first author proposed, designed, performed the experiments, and evaluated. The second author made a significant contribution to the manuscript's development and assessment.

7. Acknowledgements

Professor Dr. Suman Maloji, my supervisor, deserves my sincere gratitude for bringing this work possible. His courteous guidance and implementation of appropriate have been beneficial throughout the project.

References

[1]. P. Tupayachi, J. Pineyro, R. Callupe and R. Alvarado, "Design of an Electroencephalogram Module for Brain Computer Interface Oriented to People with Motor Disabilities," *2006 3rd International Conference on Electrical and Electronics Engineering*, 2006, pp. 1-5, doi: 10.1109/ICEEE.2006.251941.

[2]. Yuge Sun, Ning Ye and Feng Pan, "A novel design of EEG signal amplifier," *2012 24th Chinese Control and Decision Conference (CCDC)*, 2012, pp. 3369-3372, doi: 10.1109/CCDC.2012.6244536.

[3]. T. S. Kumar, V. Kanhangad and R. B. Pachori, "Classification of seizure and seizure-free EEG signals using multi-level local patterns," *2014 19th International Conference on Digital Signal Processing*, 2014, pp. 646-650, doi: 10.1109/ICDSP.2014.6900745.

[4]. C. Chiang, N. Chang, T. Chen, H. Chen and L. Chen, "Seizure prediction based on classification of EEG synchronization patterns with on-line retraining and post-processing scheme," *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2011, pp. 7564-7569, doi: 10.1109/IEMBS.2011.6091865.

[5]. P. Mathur and V. K. Chakka, "Graph Signal Processing of EEG signals for Detection of Epilepsy," *2020 7th International Conference on Signal Processing and Integrated Networks (SPIN)*, 2020, pp. 839-843, doi: 10.1109/SPIN48934.2020.9070326.

[6]. H. Hassanpour, M. Mesbah and B. Boashash, "EEG spike detection using time-frequency signal analysis," *2004 IEEE International Conference on Acoustics, Speech, and Signal Processing*, 2004, pp. V-V, doi: 10.1109/ICASSP.2004.1327137.

[7]. Vecchiato G, Astolfi L, Tabarrini A, Salinari S, Mattia D, Cincotti F, Bianchi L, Sorrentino D, Aloise F, Soranzo R, Babiloni F. EEG analysis of the brain activity during the observation of commercial, political, or public service announcements. Comput Intell Neurosci. 2010;2010:985867. doi: 10.1155/2010/985867. Epub 2009 Dec 24. PMID: 20069055; PMCID: PMC2801453

[8]. A. S. Abdulhussien, A. T. AbdulSadda and A. A. Farawn, "New Automatic EEG Epileptic Seizure Detection Approach Using Sliding Discrete Fourier Transform and Machine Learning Techniques," *2021 2nd Asia Conference on Computers and Communications (ACCC)*, 2021, pp. 26-31, doi: 10.1109/ACCC54619.2021.00011.

[9]. I. Fadl oullah, A. Mechaqrane and A. Ahaitouf, "Butterworth Low Pass filter design using evolutionary algorithm," *2017 International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS)*, 2017, pp. 1-6, doi: 10.1109/WITS.2017.7934661.

[10]. H. Oraizi, M. S. Esfahlan and E. Forati, "Design of stepped-impedance low pass filters with impedance matching by the particle swarm optimization and conjugate gradient method," *2009 European Conference on Circuit Theory and Design*, 2009, pp. 639-642, doi: 10.1109/ECCTD.2009.5275068.

[11]. J. Liu, P. Yang, X. Yang, J. Ye and Z. Yang, "Low Pass Filters Design Using Hybrid Taguchi and PSO Optimization Method," *2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, 2019, pp. 1231-1234, doi: 10.1109/IAEAC47372.2019.8997604.

[12]. S. K. Saha, S. Sarkar, R. Kar, D. Mandal and S. P. Ghoshal, "Digital stable IIR low pass filter optimization using particle swarm optimization with improved inertia weight," *2012 Ninth International Conference on Computer Science and Software Engineering (JCSSE)*, 2012, pp. 147-152, doi: 10.1109/JCSSE.2012.6261942.

[13]. A. S. Abdulhussien, A. T. AbdulSadda and A. A. Farawn, "New Automatic EEG Epileptic Seizure Detection Approach Using Sliding Discrete Fourier Transform and Machine Learning Techniques," *2021 2nd Asia Conference on Computers and Communications (ACCC)*, 2021, pp. 26-31, doi: 10.1109/ACCC54619.2021.00011.

Ms G.Sandhya kumari is a Research scholar at Department of Electronics and Communication Engineering, *Koneru Lakshmaiah Education Foundation*, Vijayawada, A.P,INDIA. She got a Bachelor’s degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Anantapur and Master’s degree in Digital Electronics and Communication Systems from Sri Padmavati Mahila VisvaVidyalayam,Tirupati,A.P,INDIA.
Her research interest on Signal Processing, Image processing.

Dr.Mahoo Vanoon is a Professor at at Department of Electronics and Communication Engineering, *Koneru Lakshmaiah Education Foundation*, Vijayawada, A.P,INDIA. He got a Bachelor’s degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Anantapur and Master’s degree from Jawaharlal Nehru Technological University,Hyderabad. He got Ph.D in Speech Signal Processing from *Koneru Lakshmaiah Education Foundation*, Vijayawada, A.P,INDIA. His research focuses on Speech Signal Processing.