2025 Fourth International Conference on Power, Control and Computing Technologies (ICPC2T)

ICPC²T
20th – 22nd January 2025
NIT Raipur

20th to 22nd January 2025

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IEEE Conference Record # 63847

2025 Fourth International Conference on Power, Control and Computing Technologies (ICPC2T) | 979-8-3315-3040-2/25/$31.00 ©2025 IEEE | DOI: 10.1109/ICPC2T63847.2025.10958733

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IEEE Catalog Number: CFP25U78-ART
ISBN: 979-8-3315-3040-2

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2025 Fourth International Conference on Power, Control and Computing Technologies (ICPC2T) | 979-8-3315-3040-2/25/$31.00 ©2025 IEEE | DOI: 10.1109/ICPC2T63847.2025.10958748

2025 Fourth International Conference on Power, Control and Computing Technologies (ICPC2T) | 979-8-3315-3040-2/25/$31.00 ©2025 IEEE | DOI: 10.1109/ICPC2T63847.2025.10958575

Analysis and Design of A Third-Order Sallen-Key and Multiple Feedback Low Pass Filter for EEG Signal Acquisition System

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Abstract—**Electroencephalography (EEG) signals are acquired to study the brain-health, brain diseases, and other neuroscience and neuroengineering applications. EEG signals are acquired by an electroencephalography signal acquisition system (ESAS) developed with the amplifier circuit, filter circuit, digitizer, and signal recording circuit. EEG signals are low-amplitude, low-frequency signals which are found very susceptible to interference from noise signals generated by motion artifacts, power sources, electrodes, and external factors. In an analog circuit of a neural potential acquisition system, we aim to amplify the signal with minimal power consumption at minimized noise level. Simultaneously it will lower the frequency spectrum so that only desired signal targetted is passed and other unwanted signals called noises are filtered out. The low-power circuit design is essential to minimize the power consumption, heat dissipation, and noise generation to ensure the high signal-to-noise ratio as well as to avoid the failure which might harm surrounding tissues. The current study innovates in developing a sophisticated low-pass filter with power reduction for recording epileptic signals. A third-order low-pass filter (LPF) is suggested whose design minimizes its transconductance at the nanoscale using the Sallen-Key (SK) and Multiple Feedback (MFB) topologies. The proposed architecture achieves a mid-band gain of 50.2 dB and a − 3 dB bandwidth that extends from 20 Hz to 500 Hz. Simulation results were obtained in a NI Multisim environment.**

Keywords— Brain health, brain diseases, electroencephalography (EEG), EEG signal, neuroscience, neuroengineering, EEG amplifier, low-pass filter, EEG signal acquisition system (ESAS).

I. INTRODUCTION

Human health information is incorporated within the physiological signals present on the body's surface. Physiological signals are vital for obtaining health information for non-invasive biomedical diagnostic methods. Biomedical apparatus [1-4], biomedical gadgets [5, 6], and biomedical sensors [7-10] are used for obtaining physiological signals from the patient being tested [11]. Physiological signals, or those produced by external stimuli such as X-rays, electrical, optical, and magnetic sources, are present on the human surface in various ways, often transformed into electrical voltage signals. The electrocardiography (ECG) signal, electroencephalography (EEG) signal, and other signals may be detected on the body surface without external stimulation [12, 13]. Bioelectrical impedance analysis[14], electrical impedance spectroscopy (EIS) [12, 15-16], impedance plethysmography (IPG) [12, 18-20], impedance cardiography (ICG), and electrical impedance tomography (EIT) are methodologies of introducing an electrical signal and measuring system response to determine characteristics of the material being examined [21-23]. The ESAS models are crucial in small-sized implantable or wearable medical equipment. These circuits must exhibit lower power consumption since failure to do so would result in increased heat generation. The ESAS circuits are designed to record impulses via electrodes within a frequency range of several hundred hertz [24-25]. Due to the low amplitude and restricted bandwidth of the pertinent signals (EEG signals), it is imperative to develop low-power EEG Signal acquisition systems (ESAS) that demonstrate high gain and appropriate frequency attributes [26-28]. An ESAS device consists of a low-noise instrumentation amplifier (LN-INA) and a low-pass filter. In the first approach, unwanted interferences are eliminated from signal processing; whereas in the subsequent approach, unwanted frequencies are removed precisely [29-32]. Operational Amplifier-based filter circuits exhibit significant power consumption, rendering them inappropriate for low-power biomedical instrumentation. The model architectures using passive components have a significant time constant attributable to their large integrated resistors and capacitors, which may affect the overall dimensions of the design. To achieve low transconductance within the range of a few nanoseconds, third-order low-pass filters (TO-LPF) make use of linear operational amplifiers (LOAs). Therefore, the capacitance range of the integrator-based filter is successfully reduced to 10 pF or less with the use of this technology. In addition to this, they provide straightforward settings for higher-order filters that are effective in terms of the amount of power they use and the amount of space they take up [29-31]. Because of the properties of the operational amplifier (OA), the effectiveness parameters associated with the filter are dependent on those qualities. A bioamplifier for capturing electroencephalogram (EEG) signals was developed with the help of bipolar pseudo resistors. However, because of the requirement for a load capacitor with a capacity of 17 pF, this design resulted in a considerable increase in the amount of power that was used. For neural spike identification, this work proposed the implementation of a Gm-C filter. The low-pass cut-off frequency of the filter may be

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