

A Low Noise Signal Conditioning Circuit for Neural Signal Acquisition

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Abstract—Neural signals, such as action potential and neural spikes require precise amplification and noise suppression for accurate acquisition. In this work, a low noise signal conditioning circuit is designed to allow detection of neural spikes from the human body. The range of signals is in microvolts which demands a proper signal conditioning system to amplify the signals and further process it. Here, a preamplifier is properly designed with sufficient gain to amplify the signal and remove the noise. This is followed by a bandpass filter capable of filtering signals, specifically from 300Hz to 11KHz and the proposed signal conditioning circuitry could achieve a pass band gain of 41.36 dB. Additionally, the design is validated for stability in terms of gain and phase margins. The circuit could achieve an SNR of 56.05 dB at 300 Hz and drops to 40.97 dB at 11 KHz with input noise applied. Its low-voltage operation and broad specification range make it suitable for diverse biomedical applications, ensuring reliable neural recording for brain studies.

Keywords—Neural signal conditioning, low-noise amplifier, bandpass filter, action potential

I. INTRODUCTION

The neural signals are bioelectrical impulses generated by neurons to communicate with each other. They form the basis of the action potential and local field potentials responsible for the communication of sensory, motor, and cognitive information across the nervous system. Action potentials or spikes and local field potentials (LFPs) are key biomarkers for understanding brain functions and diagnosing neurologically related diseases such as epilepsy and Parkinson's disease [1]. However, such signals are difficult to catch, suffering especially from biological noise such as muscle activity, etc. and interference from the environment such as electromagnetic artifacts. Action potentials, which encode communication between neurons, occupy a high-frequency band between 300 Hz to 11 kHz. Extracellular action potentials, for instance, are types of neural signals,

captured for the purpose of recording the spiking activity of individual neurons, while electroencephalographic (EEG) signals are used to register the electrical activity within larger neuron population assemblies.

The neural signals have very low amplitudes in the microvolt (μ V) range, typically 0.1 - 1 mV for spikes as small ionic currents accompanying neuronal activity. Signal conditioning is critical for neural signal processing as the raw neural signals are usually weak, noisy, or interfered with by their environmental and biological sources. The signal conditioning circuits play an important role in modern measurement systems in terms of capturing and processing low outputs of the sensors [2]. The spikes often have μ V levels whereby they cannot be identified by conventional amplification systems because of the embedded noise that causes distortion or saturation. Therefore, specialized signal conditioning circuits have been built to amplify neural activity without picking artifacts outside the band.

The proper signal conditioning enhances the signal characteristics by amplifying weak signals, filtering the unwanted noise, and ensuring that the appropriate frequency components are included in the signal and the correct information can be received, processed, and interpreted accurately and reliably for further analysis. A suitable design for a signal conditioning circuit might include several stages such as an initial low-noise preamplifier for amplification, a band-pass filter to isolate frequency ranges of interest, and a common-mode rejection mechanism to nullify external disturbances. The circuit must also consider factors such as impedance matching, noise minimization, high SNR, stability, power consumption, and protection against variations in electrode impedance [3]. By taking care of these design aspects in an optimal way, the signal conditioning circuit can effectively enable the acquisition of high-fidelity neural signals for neuroscience and medical applications.