

# Ultra-Low Power High-Input Impedance Subthreshold CMOS Neural Front-End Amplifier<sup>1</sup>

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Received March 28, 2018

Revised March 21, 2019

Accepted March 25, 2019

**Abstract**—An ultra-low power, voltage-mode front-end amplifier (FEA) for neural applications featuring subthreshold design is presented. This has been a topic of much research in implantable medical prosthetic devices during the past few decades to monitor and treat the neural disorders such as hearing or sight dysfunctions, epilepsy, Parkinson’s disease, paralysis. The FEA performs a critical signal detection operation in neural monitoring systems to ensure the biosignal fidelity. A matched double-MOS feedback technique is used to compensate the input leakage currents generated by low noise amplifier in the form of integrated circuit (IC), which is the primary reason for immense signal leakage in the input bias network. Therefore, this loop topology ensures that FEA maintains high impedance across a wide range of input frequency. The proposed FEA is implemented by using an SK Hynix 0.18  $\mu\text{m}$  CMOS process. This IC consumes 320 nW in the area of 0.016  $\text{mm}^2$  and achieves the input impedance of 44.9  $\text{G}\Omega$ , and the input-referred noise of 153  $\text{nV}/\text{Hz}^{1/2}$ .

**DOI:** 10.3103/S0735272719030051

## 1. INTRODUCTION

The acquisition device used for neural signal recording [1] is one of the most important components in a biomedical electronic system. The front-end amplifier (FEA) is the key element [2] for such a system, which senses and amplifies the neural signals such as electroencephalography (EEG), electrocorticography (ECoG), and local field potential (LFP), through electrode–tissue interfaces [3]. These signals have small amplitudes and their bandwidth varies from a few sub-Hertz (Hz) to kilo-Hz [4]. Generally, neural signal consists of the action potential (AP) or neural spikes with amplitude range of 5 to 50  $\mu\text{V}$  (at frequencies 300 Hz to 7.5 kHz) and LFP with amplitudes in the range from 1 to 50 mV (at frequencies 25 mHz to 100 Hz) [5]. Therefore, a FEA capable of sensing wide bandwidth signals near to DC is necessary [6].

The impedance of the electrode–tissue interface varies from a few  $\text{k}\Omega$  to  $\text{M}\Omega$  [7, 8] for different biosignals. However, this impedance variation in the interface forms a voltage divider network with respect to FEA [3] and causes the attenuation and data loss in neural signals. Therefore, a high input impedance FEA is essential for reducing the attenuation caused by the interface. Furthermore, it ensures the safety of the tissues by minimizing the current in the neuron. Moreover, the input leakage current, which is the majority current in the IC form [3] of the operational amplifier (Op-amp) limits the input impedance of FEA [9]. Additionally, a FEA design with low input-referred noise lowers the overall noise figure to enhance the signal-to-noise ratio (SNR) of the entire acquisition device.

In this paper, the input leakage cancellation loop (LCL) based on a double-MOS structure (DMS) [10] is presented. The Op-amp for FEA is designed by adopting the subthreshold operation regime [11, 12] and cascoded architecture [13]. The rest of this paper is organized as follows. Section 2 describes the design of the proposed FEA in detail. Section 3 presents and analyzes the results of the simulation. A brief conclusion is presented in Section 4.

<sup>1</sup> This study was supported by a research fund from Chosun University in 2016.

## ACKNOWLEDGMENTS

The author would like to thank the IC Design Education Center (IDEC), South Korea for supporting Cadence EDA tools and providing fabrication facility of Multi-Project Wafer (MPW) for Magna Chip /SK Hynix process 0.18  $\mu\text{m}$ .

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## ADDITIONAL INFORMATION

The initial version of this paper in Russian is published in the journal "Izvestiya Vysshikh Uchebnykh Zavedenii. Radioelektronika," ISSN 2307-6011 (Online), ISSN 0021-3470 (Print) on the link <http://radio.kpi.ua/article/view/S0021347019030051> with DOI: [10.20535/S0021347019030051](https://doi.org/10.20535/S0021347019030051).

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