Ultra-Low-Noise Signal-Recording Amplifier/MUX ASIC

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1. Introduction

In several biomedical and pharmaceutical researches like cardiotoxicity, scientists and clinicians can simultaneously stimulate cells and record the biomedical signals in several spots, by the use of MEAs [1]. It is therefore, desired to have an ASIC in which a MUX connects the electrode pins to either a stimulation pin or the corresponding LNA for amplification and recording. The high-voltage (HV) feature of stimulation signals demands HV switches and the low amplitude signals from electrodes need ultra-low noise amplifiers. The desired amplifier must have an input-referred noise (rms) voltage of <1.5µV, a bandwidth of 8 kHz with no high-pass filtering, non-resistive input impedance with a supply voltage of 5V, and capable of driving the sampling capacitors of the succeeding ADCs in a 0.18-µm HV CMOS technology.

2. Methods

The instrumentation amplifier, shown in Fig.1, passes the DC component of the input signal and presents a non-resistive input impedance. Assuming a maximum input signal voltage swing of 400mV$_{p\text{-}p}$ with a 4-V output swing, the amplification gain cannot exceed 20dB. With such a low gain, noise contribution due to R1-R7 will be considerable if we select large resistances to minimize power consumption. A simple RC low-pass filter followed by a voltage buffer is used to drive the sampling capacitor of the ADC. The main challenge in designing the LNA is thus, optimally selecting the values of the size and the current of the transistors in OP1-2 to achieve the desired extremely small value of the input-referred noise voltage.

The desired HV switch, made up of MOSFETs with $V_{GS,max}$=5 V, must pass 20V$_{p\text{-}p}$ (the first challenging issue), and have robust on-resistance insensitive to process and voltage variations. The other challenging feature of the desired switch is having a fast transition time because in some applications there is a need to switch to the recording mode immediately after the stimulation mode. The proposed switch, is inspired by the bootstrapped switch in [2], consisting two large transistors Q1-2 as the core of the switch to pass the stimulation signal, Q3-Q6, R1, C1 and S1 to turn off the switch and Q7-Q10, R2, C2, S2 and D1 to turn it on. The faster $V_{GS1,2}$ settles, the smaller the transition time becomes; but more I_{Q9} will be needed. Capacitors C1 and C2 are added to make a large amount of current at the beginning of the transition; so $Cg_{1\&2}$ receive sufficient current to be charged much faster causing the transition time to be considerably smaller.

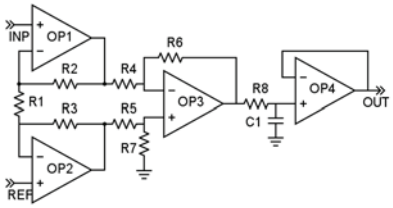

Fig. 1 The schematic of the proposed amplifier.

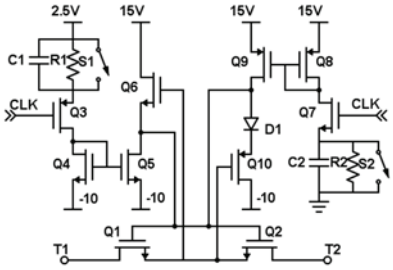

Fig. 2 The schematic of the proposed switch.

3. Results

Both the measurement results of the amplifier and the simulation results of the (2nd version of) HV switches are summarized below. It can be observed that the objectives are completely met.

Table 1: measurement results of the proposed LNA

Input referred noise	Power (5V power supply)	Area*	Input capacitance	THD (4V swing)
1.3uV	**4.45mW**	**900×190 um²**	**< 4.5pF**	**-60dB**

*The LPF large capacitor is placed on top of the whole circuit using MIM capacitor

Table 2: simulation results of the proposed HV switch

R_{on}	Off isolation	Static power consumption		Area	T_{on}	T_{off}
		On state	Off state			
100 Ω	**-86dB***	**40µW**	**20µW**	**0.015mm²**	**50ns**	**10ns**

*@ 20Vp-p, f=10 kHz, RL=10 kΩ

References

[1] S. Khoshfetrat Pakazad, "Stretchable Micro-Electrode Arrays for Electrophysiology Design, Fabrication and Characterization," PhD Dissertation, TUDelft, 2015.

[2] C. S. Birk, "Four-Quadrant Bootstrapped Switch Circuit," US Patent, WO2013036382 A1, Mar 14, 2013.