8-Channel Optical Stimulus & 16-Channel Chopper Technique Recording: A Dual-Module Neuromodulation Integrated System

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***Abstract*— This paper proposes a neuromodulation integrated circuit (IC) system that includes an 8-channel optical stimulation module and a 16-channel recording module. The optical stimulation system is based on a switched current mode DAC, while the recording module utilizes a chopper amplifier. Simulation results demonstrate that the driving current can be adjusted from 14 µA to 29 mA for the stimulator, and the recording module achieves a 34 dB gain, 20 kHz bandwidth, and 6.951 µVrms input-referred noise.**

I. INTRODUCTION

The neuromodulation IC system, illustrated in Fig. 1, features an eight-channel LED stimulator and a sixteen-channel chopper amplifier. The stimulator module is based on a switched current mode digital-to-analog converter (DAC), capable of driving customized micro-LEDs for optical stimulation. To record very weak neural signals, the recording module adopts a chopper amplifier structure that offers lower noise compared to the normal amplifier structure. The entire IC system is designed using the TSMC 65 nm GP process.

II. METHODS

Before designing the stimulator circuit, the customized blue light micro-LED was tested for its electrical characteristics, which has a turn-on voltage of 2.5V. Under the condition when the current is 10mA, the voltage between the cathode and anode of the LED is approximately 3V, and the optical power density shows 2.3mW/mm² [1]. Based on its performance, a mimic micro-LED circuit was designed for stimulator's driving capability simulation. On the strength of a programmable 6-bit switched current mode DAC, the stimulator allows precise stimulation by adjusting the input clock signal, thereby controlling the micro-LEDs' output light intensity.

The neural signal, typically in the range of several tens of microvolts, necessitates a highly sensitive recording module [2]. To address this, the system employs a chopper amplifier as a front-end amplifier, which separates circuit noise and neural signals into different frequencies, enhancing the signal-to-noise ratio (SNR). The input MOSFET of the amplifier is designed with a larger gm/Id to improve noise-power efficiency, while the current mirror MOSFET is designed with a lower gm/Id for precise current mimicry. Although the chopper amplifier reduces circuit noise, it introduces chopper glitches in the output signal. To mitigate these glitches, a switched capacitor-based filter is connected to the chopper amplifier.

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III. RESULTS

Simulation results indicate that the 6-bit stimulator can generate driving currents ranging from 14 µA to 29 mA without static power consumption. The recording module's simulation results show each recording channel consumes 4.8 µW of power, with a 20 kHz bandwidth, 34 dB gain, and 6.951 µVrms input-referred noise.

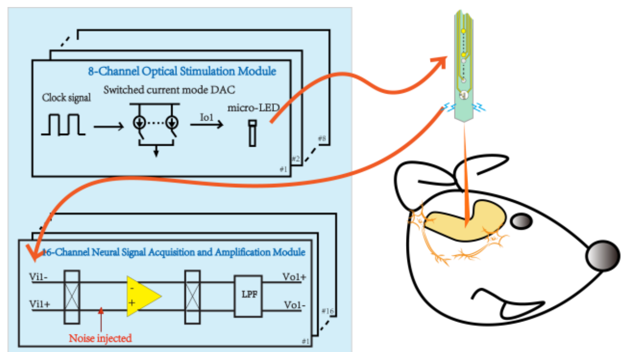

Figure 1. Structure of the dual-module neuromodulation integrated system.

IV. DISCUSSION & CONCLUSION

This paper introduces a multi-channel neuromodulation IC system based on a switched current mode DAC and chopper amplifier. By employing chopper techniques and gm/Id design methods, the recording module achieves lower input-referred noise and better noise-power efficiency. However, the current system cannot address artifacts, which will be the focus of future work.

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