

CMOS NEUROCHIP FOR STIMULATION AND RECORDING OF ELECTROGENIC CELLS

F.Heer¹, S.Hafizovic¹, W.Franks¹, A.Blau², C.Ziegler², S.Taschini¹, A.Hierlemann¹ & H.Baltes¹

¹Physical Electronics Laboratory, ETH Zurich, 8093 Zurich, Switzerland.

²Dep. of Physics, Kaiserslautern University of Technology, 67663 Kaiserslautern, Germany.

ABSTRACT: An array of platinum electrodes [Fig. 1] has been integrated in standard CMOS technology that allows each electrode to be simultaneously used for stimulation and recording. The microelectrode array exhibits a shifted-electrode design for improved electrode stability. The system architecture includes A/D converters for each row and a digital control unit that scans the array and provides a digital interface with the outside world.

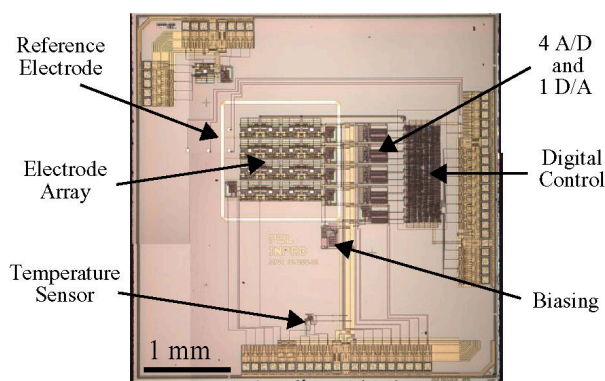


Fig. 1: Micrograph of CMOS Chip with main components.

SYSTEM ARCHITECTURE: The 4.4 x 4.4 mm² CMOS chip presented here consists of a 4-by-4 electrode array with an integrated reference electrode [Fig. 1]. Fabrication was performed using an industrial 0.6 μm CMOS process at Austriamicrosystems AG, Austria. The electrodes are 30 x 30 μm² with a 250-μm pitch.

Any electrode subset can be used for stimulation at any time, recording from all electrodes is possible during the measurement period. Stimulation and readout operations are controlled by the on-chip digital circuitry.

Each electrode is equipped with a band-pass filter for readout. The corner frequencies of the filter are specified at 100 Hz and 50 kHz, since neural signals have a frequency of about 1 kHz [1-3]. Extracellular neural signals are weak, up to hundreds of microvolts [1-3], therefore an overall gain of the filter of 1000 was used. Buffering of the signals is mandatory in going to larger arrays with several hundred electrodes because it allows for fast multiplexing, resulting in a high sampling frequency at a small number of A/D converters.

TRANSDUCER DESIGN: A simple 2-mask post-processing procedure is used to cover the metal of the CMOS process (aluminum) with biocompatible platinum. The transducer has been electrically characterized and the experimental results have been fitted to an equivalent circuit model presented in [1].

RESULTS: Operation of the stimulation circuitry is demonstrated by generating a square-wave stimulus on chip. The resulting signal on a selected electrode was

measured using a probe tip [Fig. 2A]. The band-pass filter has been electrically characterized, using a gain-phase analyzer (HP-4194A), with results shown in [Fig. 2B]. The equivalent input noise of the filter is below 9 μV_{RMS} (100 Hz - 50 kHz) and was measured with a spectrum analyzer (HP-4195A). First tests were performed using heart cells from chicken embryos, the signals of which are shown in [Fig. 3].

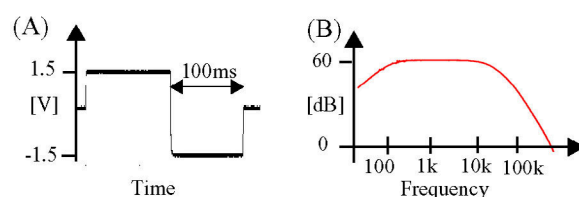


Fig. 2: Tests with on-chip generated stimulation signal (A). Transfer function of the band pass filter (B)

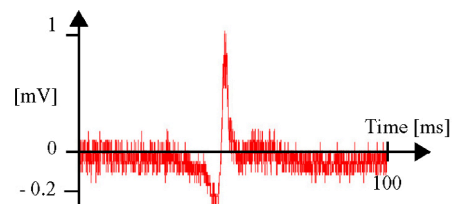


Fig. 3: Typical Spike from a chicken heart cell. Sampling frequency was set to 20 kHz.

CONCLUSION: A microelectrode array capable of simultaneous recording and stimulation of electrogenic cells has been presented. The functionality of the circuitry components has been verified with regard to the initial specifications. Mammalian neural signals are much smaller than the signals from chicken heart cells, therefore the performance of the measurement setup needs further improvement.

REFERENCES: ¹W. Franks, et al. (2003) CMOS Monolithic Microelectrode Array for Stimulation and Recording of Natural Neural Networks, *Transducers*. ²B.D. deBusschere, et al. (2001) Portable Cell-based Biosensor System Using Integrated CMOS Cell-cartridges, *Biosensors & Bioelectronics*, 16:543-56. ³Q. Bai, et al. (2001) Single-Unit Recording with Active Microelectrode Arrays, *IEEE Transactions on Biomedical Engineering*, 48(8):911-20.