

Concept for high channel systems for cell sensing

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In high-channel electrode systems for parallel impedance measurements on cells and biological tissues, a multiplexer is typically used to sequentially connect all electrodes to the impedance measuring device. This has the disadvantage that, especially with high-channel systems, the complete measurement across all electrodes takes a relatively long time, especially if an entire spectrum is to be recorded. As a result, cell dynamics in the subsecond range can only be achieved selectively over just a few electrodes.

In an alternative concept, the impedance is not directly measured in the frequency domain, but calculated from the relaxation behavior after a voltage step (time domain). The voltage step is applied centrally via a distant electrode, and the current through each electrode of a multi-electrode array is measured.

A special feature of relaxation in biological objects is the exponential decay of the current, which is primarily caused by the charging of membrane structures. Due to the rapid change at the beginning and the increasingly smaller change in the current after the step, it is sufficient to scan quickly at the beginning and then successively increase the intervals between the scanning points. A simple sampling regime of this type would violate the sampling theorem and inevitably lead to nonsensical results. This is counteracted by integration between the sampling points. For this purpose, an integrator is placed behind each electrode. This arrangement has the advantage that all integrators can be started simultaneously, whereby the integrated currents are present at all outputs simultaneously for one integration period. After these voltages have been read, the integrators are reset and integrated over the next period. In practice, four time instances are sufficient for one decade, meaning that only twenty-four sampling points are required to record a spectrum over six decades.

In this way, for example, a multi-electrode array with 10,000 electrodes could be realized [1], in which the impedance spectrum between 5 kHz and 1 MHz can be recorded across all electrodes within one second (8 seconds in the cited paper). Alternatively, individual electrodes can be recorded at a rate of 1,000 measurements per second.

References:

- [1] Gansauge, C., K. Schieke, and U. Pliquett. "ECIS with 10,000 Channels—a Feasibility Study on Biofilm Growth." *International Journal of Bioelectromagnetism* 23.2 (2021).