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An automatic transimpedance gain control circuit for analogue front-ends of drifting amperometric biosensors

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Abstract

When amperometric biosensors drift, their sensitivity drops with time: the same difference in detected concentration value ΔC results in lower sensor output current ΔI as the measurement/monitoring time progresses. This limitation affects the longevity of biosensors. To counterbalance for the drop in sensitivity, manual adjustment of the I-to-V transimpedance gain is usually applied. This paper presents an automatic transimpedance gain control circuit suitable for switched-capacitor-based current analogue front-ends. The circuit has been fabricated in the $0.35\mu m$ AMS technology, occupies an area of $0.028mm^2$ and consumes $14.5\mu W$ from a $3.3V$ supply. Measured results confirm the automatic selection between three values of transimpedance gain, namely 1,10 and $100G\Omega$ each optimised for sensor current range values of $\pm 1.65nA$, $\pm 165pA$ and $\pm 16.5pA$ respectively. Though the reported topology has been tailored for glucose/lactate amperometric biosensors of slow temporal dynamics, its parameters can be made to match the conditions of other physiological/physical processes in need of monitoring.

Keywords: automatic gain control, transimpedance, amperometry

1. Introduction

Continuous monitoring of human body glucose and lactate levels has proven to be a good indicator for certain diseases (e.g. diabetes) and functionality of organs (e.g. liver). For the detection of both chemicals the biosensors rely on amperometry (measurement of current generated from "substance specific" chemical reaction(s))[1]. Such biosensors are also used for the monitoring of traumatic brain injury (TBI) patients. TBI can be defined as non-degenerative, non-congenital brain trauma due to an external mechanical force. TBI is a major cause of death and disability in all age groups and the leading cause of death and disability in working people and among young adults. It has been studied and reported that the monitoring of certain electrical (e.g. ECoG) and chemical signals, including glucose and lactate, may lead to the earlier detection and ultimately the prevention of a secondary brain trauma [2]. Biosensors coupled to a microdialysis sampling probe, which has been placed in the brain tissue at risk of secondary damage, have been shown to provide insight into the neurometabolic activity of tissue during spreading depolarisation events [3] [4]. The concentration measurements of such chemicals in the extracellular fluid of brain tissue are translated to *nA* ranging currents characterised by temporal dynamics close to DC. Although for the first hours of use the sensitivity of such biosensors is adequate, its decline after long periods of operation results into malfunctioning when the sensed current differences ΔI become so small - for the same concentration difference ΔC - that cannot be detected reliably. This limitation is often referred to as "(bio)sensor drift" [1], and in practice means

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