Abstract

CMOS has been wildly used in biomedical applications for personalized diagnosis and treatment. The biomedical application of CMOS can be divided into two broad categories: invasive and noninvasive treatments. The invasive procedure includes the micro-electrical stimulation and recording systems that involve microelectrode insertion on tissue for neurological and physiological studies and clinical treatments. The noninvasive procedure includes the wearable health systems, where the optical sensing photoplethysmography (PPG) sensor has been of recent interest due to the electrode-free operation for the heart-rate, the variability extraction for heart-rate and blood oxygen level monitoring (SpO2).

In the micro-electrical stimulation/recording systems, the electrode-tissue interface impedance plays an important role to ensure charge balance, maintain stimulus intensity, limit the over-potential of the electrode under the water window, prevent tissue damage, and more. It is therefore crucial to have an equivalent circuit model with precise fitting to the practical behavior of the electrode-electrolyte interface, which confers great benefits in biomedical studies, circuit designs, impedance monitoring, etc. Meanwhile, the electrode-electrolyte interface impedance will change over time after the implantation of the electrodes in clinical applications, possibly due to tissue growth, inflammation, electrode erosion and so on. It is also vital to monitoring the electrode-electrolyte interface impedance characteristics. For the PPG sensor in non-invasive wearable application, a cost-effective approach is the key requirement in all internet of things (IOT) applications.

Consequently, a hybrid-π model and parameter extraction method is explored for electrode-electrolyte interface characterization with superbly accurate reactance in high

frequency biomedical applications. A training-based compensation scheme is proposed for the non-ideal circuit effects in I/Q impedance measurement architectures, which has been verified through simulation results obtained from Simulink analysis. A current-excited triple-time-voltage oversampling impedance sensing method is provided to deduce different component values by solving triple simultaneous electric equations (TSEEs) at different time nodes during current excitation. To reduce the power consumption, a time-domain impedance sensor readout circuit in the absence of Analog-to-Digital Converter (ADC) is developed. This prototype is fabricated in 0.18-μm CMOS technology. It consumes only 9.84 to 73.2 nJ of energy, and requires merely 3 ms per measurement. As for the PPG sensor in non-invasive wearable health systems, having low power consumption is also vital. A PPG sensor with time-to-digital converter architecture for low power consumption without the use of high accuracy ADC is therefore proposed whereby the design has been verified by fabrication using the 0.18-μm CMOS technology.