Master thesis : Design and development of non-contact electrodes electrooculogram acquisition system for sleep measurements

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Physiological signal monitoring plays an important role in the assessment of sleep quality and the diagnosis of sleep disorders such as sleep apnea. During sleep, eye movements provide valuable information about sleep stages, especially during rapid eye movement (REM) sleep. The electrooculogram (EOG) is commonly used in sleep studies to detect eye movements and to support sleep-stage classification. However, conventional EOG acquisition systems rely on wet or dry contact electrodes placed near the eyes which can be uncomfortable, restrictive and poorly tolerated during overnight or long-term measurements. These limitations motivate the development of alternative acquisition techniques that improve comfort and ease of use while maintaining sufficient signal quality.

This work presents the design, development and experimental validation of a non-contact electrooculogram (EOG) acquisition system. It is intended for easy-to-use, comfortable by reducing skin irritation and wearable physiological monitoring, making them more suitable for overnight and repeated measurements. Non-contact electrodes measure biopotential signals through a thin insulating layer, such as fabric. However, they also introduce very high electrode–skin impedance and increased sensitivity to environmental noise, especially power-line interference.

The system was first modeled and analyzed using LTSpice simulations to understand the impact of modified skin–electrode interface of non-contact electrode. A dedicated PCB was designed and implemented, integrating an analog front-end with impedance buffers in the non-contact electrodes and amplification stages, filtering and grounding strategies in the main board. The design is made versatile to allow for the use of wet, dry or non-contact electrodes, adjustable gains and filters to study their impact on signal quality. After troubleshooting, a repeatable measurement protocol was defined with timed eye-movement phases to ensure consistent comparison between experimental runs.

Experimental recordings were performed using fully non-contact recording electrodes and a grounded reference electrode. The output signal was acquired with an oscilloscope and post processed by a Python code. This code is dedicated to plot the output but can also apply digital 50 Hz notch filtering, compute the signal-to-noise ratio (SNR), apply the Fast Fourier Transform (FFT) over the signal. The results show that the system is able to detect typical eye activities such as left and right movements, blinking and random eye movements.

Despite these encouraging results, the measurements remain strongly affected by power-line interference and by experimental factors such as reference electrode coupling, skin moisture, electrode pressure, and environmental conditions. Overall, this work demonstrates the feasibility of non-contact EOG acquisition as a proof of concept for sleep monitoring applications.