DESIGN AND ANALYSIS OF ARTIFACT-RESISTANT FINGER PHOTOPLETHYSMOGRAPHIC SENSORS FOR VITAL SIGN MONITORING

by

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ABSTRACT

A miniaturized, telemetric, photoplethysmograph sensor for long-term, continuous monitoring is presented in this thesis. The sensor, called a "ring sensor," is attached to a finger base for monitoring beat-to-beat pulsation, and the data is sent to a host computer via a RF transmitter. Two major design issues are addressed: one is to minimize motion artifact and the other is to minimize the consumption of battery power. An efficient double ring design is developed to lower the influence of external force, acceleration, and ambient light, and to hold the sensor gently and securely on the skin, so that the circulation at the finger may not be obstructed. To better understand the mechanism of motion artifact by external forces, a comprehensive mathematical model describing the finger photoplethysmography was developed and verified by finite element method, numerical simulation and experiments. Total power consumption is analyzed in relation to the characteristics of the individual components, sampling rate, and CPU clock speed. Optimal operating conditions are obtained for minimizing the power budget. A prototype ring sensor is designed and built based on the power budget analysis and the artifact-resistive attachment method. It is verified through experiments that the ring sensor is resistant to interfering forces and acceleration acting on the ring body. It is also shown that the device meets diverse and conflicting requirements, including compactness, motion artifact reduction, minimum loading effects, and low battery power consumption. Benchmarking tests with FDA-approved photoplethysmograph and EKG reveal that the ring sensor is comparable to those devices in detecting beat-to-beat pulsation despite disturbances. The long-term monitoring experiment shows that this device can effectively provide a considerable amount of artifact-free vital sign information in everyday life. Finally, guidelines for designing the ring sensor are proposed based on the analyses and the experiment results.

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