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FINAL ORAL EXAMINATION

OF

PARVIN AKHKANDI

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
(ELECTRICAL ENGINEERING)

Monday, March 17, 2025, 10:30 A.M. (Online)

DISSERTAION COMIMTTE

Dr. Reza Abdolvand, Chair
Dr. Vikram Kapoor
Dr. Enxia Zhang
Dr. Kenle Chen
Dr. Hyoung jin Cho

DISSERTATION

MEMS-BASED AIRFLOW SENSOR FOR APNEA DETECTIONUSING TIME-OF-FLIGHT-TECHNIQUE

Sleep is essential for overall human health, influencing cognitive, emotional, and physical well-being. Respiratory-related sleep disorders, particularly obstructive sleep apnea (OSA), require early detection and effective treatment to prevent serious health complications. This dissertation explores innovative advancements in respiratory monitoring sensor development techniques, aiming to improve the diagnosis and management of sleep disorders. The sensor in this work incorporates a pair of Thin-film Piezoelectric on Substrate (TPoS) MEMS resonators operating at ~25 MHz, embedded in two oscillator circuits where frequency variations reflect changes in temperature and humidity caused by respiratory airflow. By precisely measuring airflow travel time between the resonators, the sensor calculates real-time flow rates and velocities with high sensitivity to subtle breathing pattern changes. A laminar airflow channel is carefully designed to minimize turbulence, ensuring more accurate Time-of-Flight-based airflow measurements. The system has undergone extensive experimental validation, including tests with a controlled respiration simulator that replicates human breathing patterns. Results show high precision and linearity, with the sensor accurately measuring flow rates between 0 and 10 L/min and velocities from 0 to 2 m/s, achieving an accuracy of 97.85%. Additionally, the system demonstrates excellent stability, featuring low phase noise, strong frequency response, and a high signal-to-noise ratio (SNR). The use of MEMS-based oscillators further enhances system robustness, while its low power consumption makes it ideal for continuous, real-time monitoring in both clinical and home settings.

SELECTED PUBLICATIONS

- Development of a MEMS-Based Resonant Airflow Sensor for Apnea Detection Using Time-of-Flight Technique. **P Akhkandi**, H Mahdavi, R Abdolvand, IEEE Sensors Journal
- A Wide-Dynamic Range (-40 °C to 180 °C) Active Wireless MEMS Temperature Sensor With 7m °C Sensitivity. Shuwei Ji, **Parvin Akhkandi,** Yu Qi, Reza Abdolvand, Hossein Miri Lavasani, IEEE Sensors Journal
- A Battery-Less Wireless Respiratory Sensor Using Micro-Machined Thin-Film Piezoelectric Resonators. Sina Moradian, **Parvin Akhkandi**, Junyi Huang, Xun Gong and Reza Abdolvand, Sensors

- Development of a MEMS-Based Resonant Airflow Sensor for Apnea Detection Using Time-of-Flight Technique. **P Akhkandi**, H Mahdavi, R Abdolvand, IEEE Sensors Journal
- A Wide-Dynamic Range (-40 °C to 180 °C) Active Wireless MEMS Temperature Sensor With 7m °C Sensitivity. Shuwei Ji, **Parvin Akhkandi,** Yu Qi, Reza Abdolvand, Hossein Miri Lavasani, IEEE Sensors Journal
- A Battery-Less Wireless Respiratory Sensor Using Micro-Machined Thin-Film Piezoelectric Resonators. Sina Moradian, **Parvin Akhkandi**, Junyi Huang, Xun Gong and Reza Abdolvand, Sensors