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Development of a Non-Contact In-Vehicle Human Presence Detection Sensor Using Spatial Potential Fluctuations

Kenji Kouno [1)] Hiroyuki Suto [2)] Yusuke Yokota [1)] Yusuke Umetani [2)] Yoshihiro Suda [1) 3)]

1) The University of Tokyo, Institute of Industrial Science
4-6-1 Komaba, Meguro, Tokyo, 153-8505, Japan
2) Toyota Motor Corporation
1200 Mishuku, Susono, Shizuoka, 410-1193, Japan
3) Tokyo University of Technology
1404-1 Katakuramachi, Hachioji, Tokyo, 192-0982, Japan

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Child Presence Detection (CPD) systems are increasingly required to prevent accidents involving children left inside vehicles. Although millimeter-wave radar and camera-based systems are widely used, they have limitations in cost, installation constraints, and environmental robustness. This study proposes a non-contact respiration sensing method based on spatial potential fluctuations around the human body caused by respiration and body motion.

A novel single-electrode sensor with a pseudo-differential configuration is developed to improve noise immunity under strong electromagnetic interference. As illustrated in Fig.1, the signal acquired by a single electrode is divided into two parallel paths with different frequency characteristics. One path preserves low-frequency components associated with respiration, while the other emphasizes higher-frequency components dominated by common-mode noise. These two signals are then combined using an instrumentation amplifier to form a pseudo-differential output. This configuration effectively cancels common-mode noise such as power-line interference while maintaining respiration-related signals.

The noise suppression performance was evaluated in a controlled electric field environment. As shown in Fig.2, the conventional sensor output is dominated by 50 Hz noise, making low-frequency respiration signals difficult to identify. In contrast, the proposed sensor significantly suppresses the 50 Hz component and clearly extracts the respiration signal around 0.5 Hz. The signal-to-noise ratio (SNR) is improved by several decibels across the tested frequency range.

To demonstrate practical applicability, in-vehicle experiments were conducted. As shown in Fig.3, the sensor output clearly reflects respiration activity: periodic fluctuations are observed during breathing, while the signal becomes stable during breath-holding. In addition, respiration signals were successfully detected under different seating positions and partial occlusion conditions, and robustness against in-vehicle noise, including engine operation, was confirmed.

These results indicate that the proposed sensor enables stable, non-contact detection of respiration-related signals in a vehicle environment. The sensor is expected to serve as a low-cost complementary solution for CPD systems alongside existing sensing technologies.

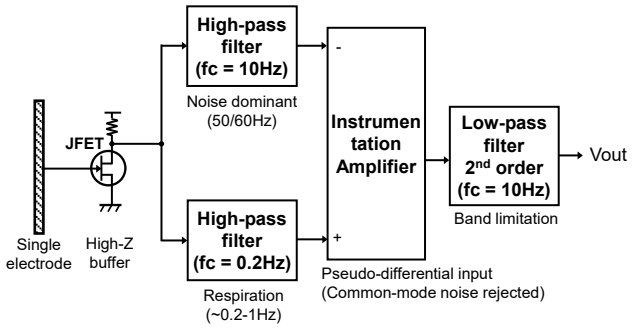

Fig.1 Concept and configuration of the proposed sensor

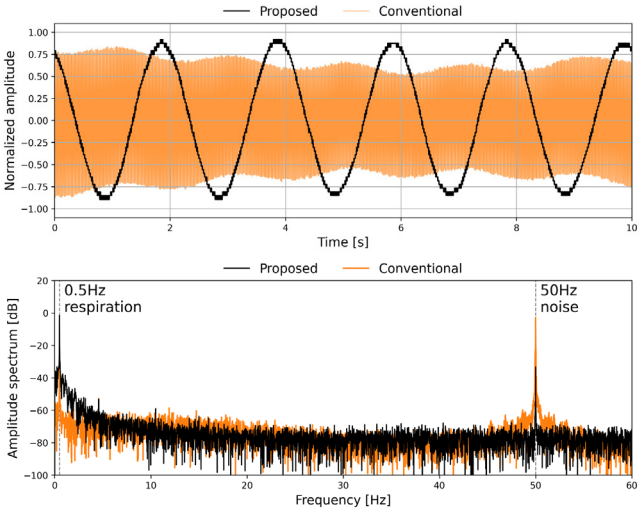

Fig.2 Comparison of sensor outputs (0.5 Hz signal + 50 Hz noise)

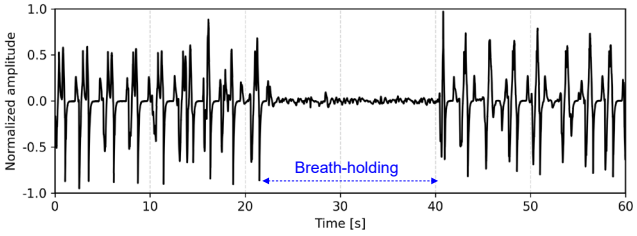

Fig.3 Time waveform during breathing and breath-holding