Chapter 7
Smart Highways-Based Piezoelectric Vehicle Speed Sensor

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ABSTRACT

In this chapter, the authors proposed a piezoelectric based vehicle speed sensor. The sensors produce pulses when stressed by a vehicle's front and back wheels, passed over them. Due to the vehicle physical dimension, the sensor pulse, due to the back wheel stressing, has some delay time as compared with the front wheel sensing pulse, due to the front wheel stressing. The time delay between these pulses is estimated using microcontroller program. Then, the program computes the vehicle speed from the distance to time delay ratio.

BACKGROUND

In recent years, there is an increasing demand to monitor the vehicle speed in smart highways and roads. Detection speed violation is essential to control the traffic. Also, type of vehicle is required to make a complete study about vehicles passing on that road.

Different state-of-the art sensor technologies were implemented to sense and detect the vehicle movement. The sensing technologies include the use of Anisotropic Magneto-Resistive (AMR) with piezoelectric sensors (Markevicius et al., 2019, 2020), image sensor (Lu et al., 2020), three point-laser sensors (Keipour et al., 2022), distributed fiber-optic acoustic sensor (Liu et al., 2018, 2019), three-

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axis digital magnetic sensors (Markevicius et al., 2018), wireless magnetic sensor network (Zhang et al., 2017), micro-electromechanical system (MEMS) SmatRock sensors (Zhang et al., 2021), camera (Shim et al., 2021), and GPS and MEMS gyro (Juang et al., 2015).

Table 1 illustrates these sensor technologies. The table also shows the speed estimation algorithms (SEA) and system principle. It also highlights some merits and challenges. The SEA includes adaptive signature cropping (ASC), pulse extraction, feature extraction, frame difference method (FDM), Image motion detection (IMD), laser change of Hight triggering (LCOHT), visual servoing controller (VSC), wavelet-denoising algorithm (WDA), dual-threshold algorithm (DTA), cross correlation (CC), sum of absolute differences (SAD), circular convolution (CCON), signals centres of mass (SCOM), dynamic time warping (DTW), Normalized cross-correlation (NCC), smoothed coherence transform (SCOT), phase transform (PHT), playback speed (PBS), and Kalman filtering. These algorithms can be classified as a time domain approaches, frequency domain approaches, or a combination between them. Most of these algorithms detect the vehicle, estimate the speed, and classify the vehicle type.

The comparison shows wide variations of the sensing technologies and speed estimation algorithms. Although Table 1 addresses differences between these technologies and estimation algorithms, the decision about the optimum system is not available due to the lack of large database needed in testing and comparison. The speed estimation is open research and currently under development.

The aim of this chapter is to propose a novel piezoelectric based vehicle speed sensor system. The system detects the moving vehicle in highways using piezoelectric array sensors placed in all lanes. The layout of the proposed array sensors is shown in Figure 1. These sensors generate pulses according to the piezoelectric generator effect. Then the pulses are processed to estimate the speed using speed estimation algorithm. A hardware and software testbench are developed to validate the research result and can become a seed to create future courses related to the power and energy area. A simulation is also provided in this chapter using MATLAB and SIMULINK. Also, experimental testing is conducted using our design prototype. Results have shown a considerable accuracy in sensing the vehicle speed when varied according to the highways speed limits, and when the input signal is subjected to a disturbance noise signal.

The motivation and contribution of this chapter is as follows:

1. Demonstrate the design of the proposed piezoelectric speed sensor and how it works.
2. Explain the sensor signal conditioning circuit needed to produce the sensor output pulses.

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