

Abstract

Inductive Loop Detectors (ILDs) are the most commonly used sensors in traffic management systems. This work provides a system capable of obtaining simultaneous inductive signatures of vehicles traveling on a roadway with minimal cost. We use this prototype to propose a novel method for vehicle classification based on only one signature acquired from a sensor single-loop, in contrast to standard methods using two sensor loops.

1 Inductive Loop Detectors

ILDs are used in traffic management systems to estimate several vehicle characteristics such as speed and length. They consist of one or more coils with one or more turns (usually 3 to 5) embedded in the road pavement; isolated cables for the connection from the coils to the control cabinet; and the electronic equipment (i.e., the detector) inside the cabinet. A vehicle stopping or moving over the coil of an ILD induces Foucault currents, which reduce the coil inductance and change the frequency (and thus the period) of the oscillation generated by an electronic detector.

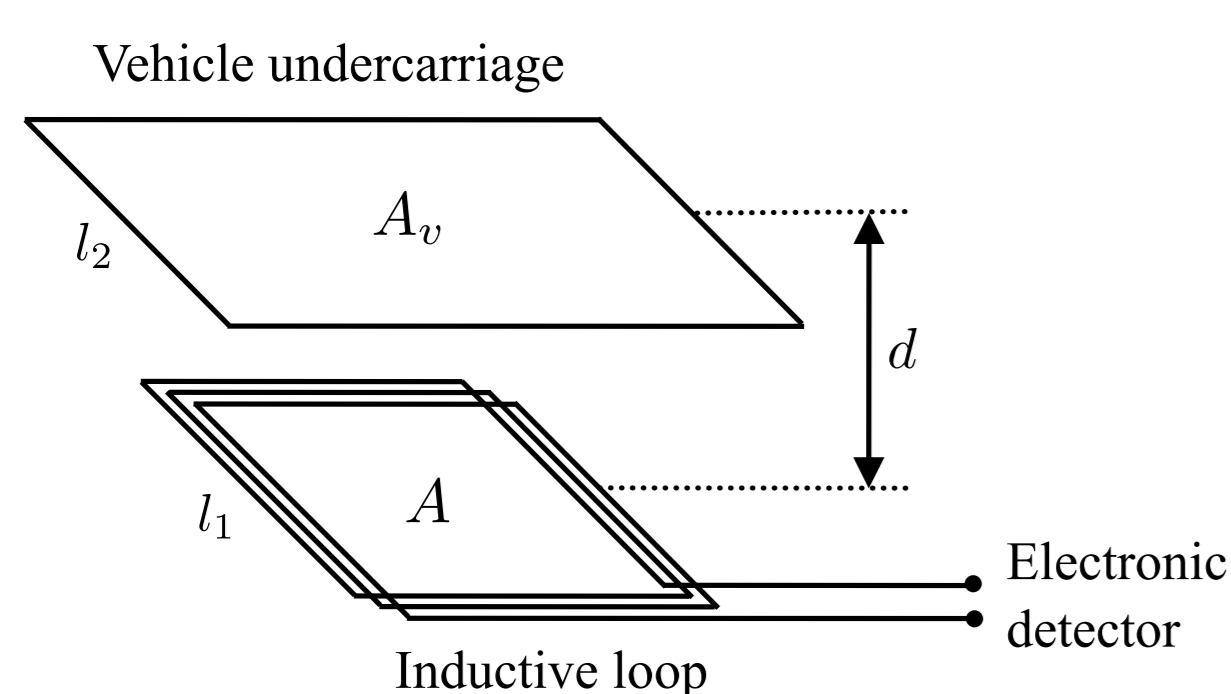


Figure 1

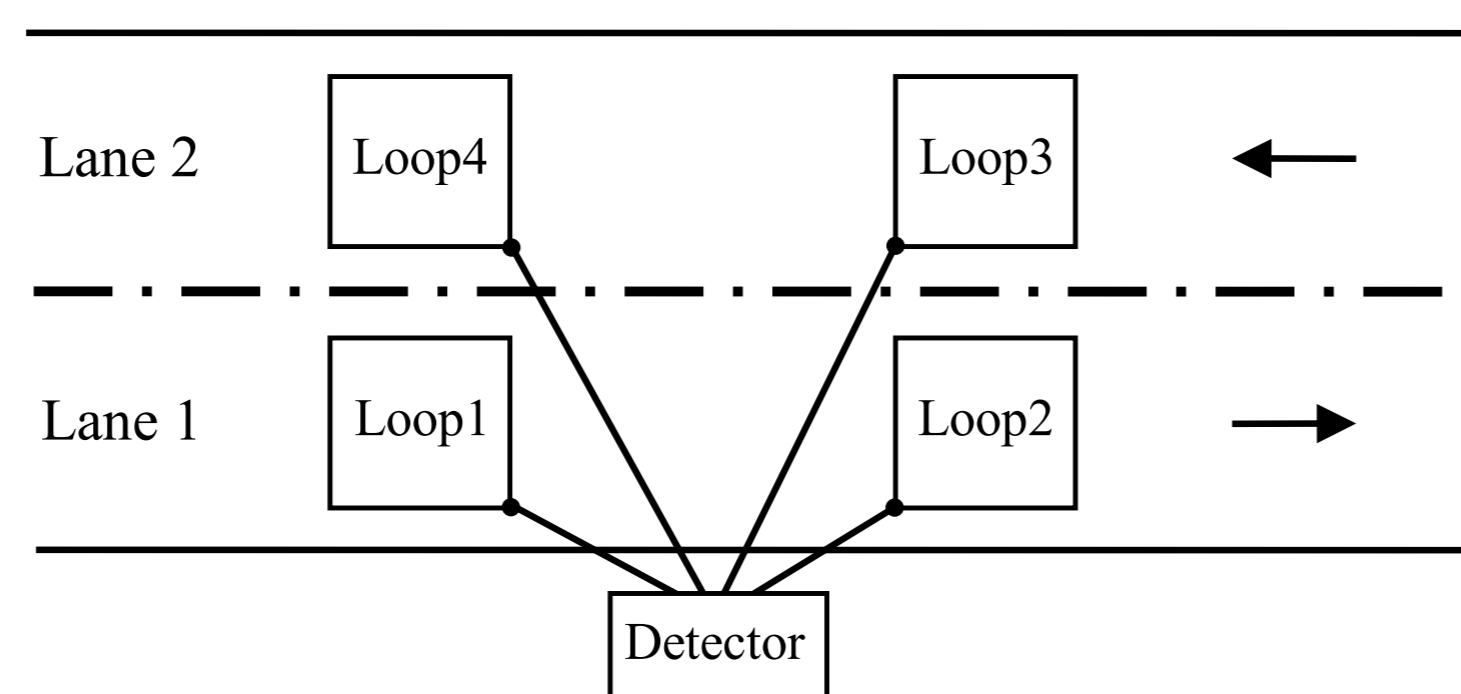


Figure 2

2 Hardware prototype

In this section we describe our implementation of an ILD for vehicle classification based on Time-Division Multiplexing (TDM) with multiple oscillators.

Fig. 3 shows the schematic of a Colpitts oscillator based on a pnp transistor in common base configuration. The oscillation frequency is determined by the parallel resonant circuit formed by the inductance L_1 and the equivalent capacitor C_T obtained from the serial connection of C_1 and C_2 .

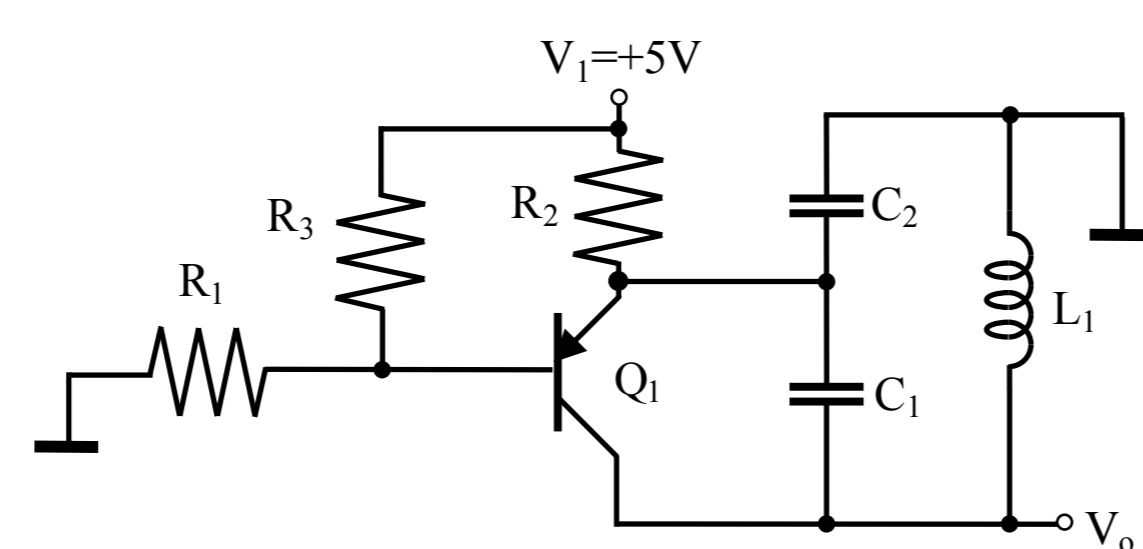


Figure 3

Fig. 4 shows a block diagram of the comparison and capture process necessary to measure the oscillation period automatically.

The pulses from the oscillation loop that has been selected as input are carried to a counter input, so that when a fixed number of pulses m is reached, the measured value N is captured from a timer working at the frequency f_r of the reference clock signal.

Since the basic measurement process is performed by hardware using interruptions, the delay time of interruption attention (known as *latency*) is not critical.

Fig. 5 shows the practical implementation of the multiplex system with eight coils. It consists of eight Colpitts oscillators connected to eight inductive loops and an analog multiplexer which selects, at each instant, the oscillation signal of one of the loops using a decoder circuit. The use of eight channels allows the registration of signatures of up to four lanes with dual loops in each lane or of up to eight lanes with simple loops in each lane. Using eight oscillators instead of a single one allows us to avoid the introduction of an analog multiplexer into the oscillation loop, which would be an additional error source.

The output signal of the multiplexer is carried to a shaping circuit, which converts the sinusoidal signal at its input into a digital pulse. That digital pulse is the input at the counter in the micro controller, which manages the entire system.

A Compact Flash (CF) memory is employed for the recording of the signatures that will be subsequently analyzed by a computer using signal processing algorithms.

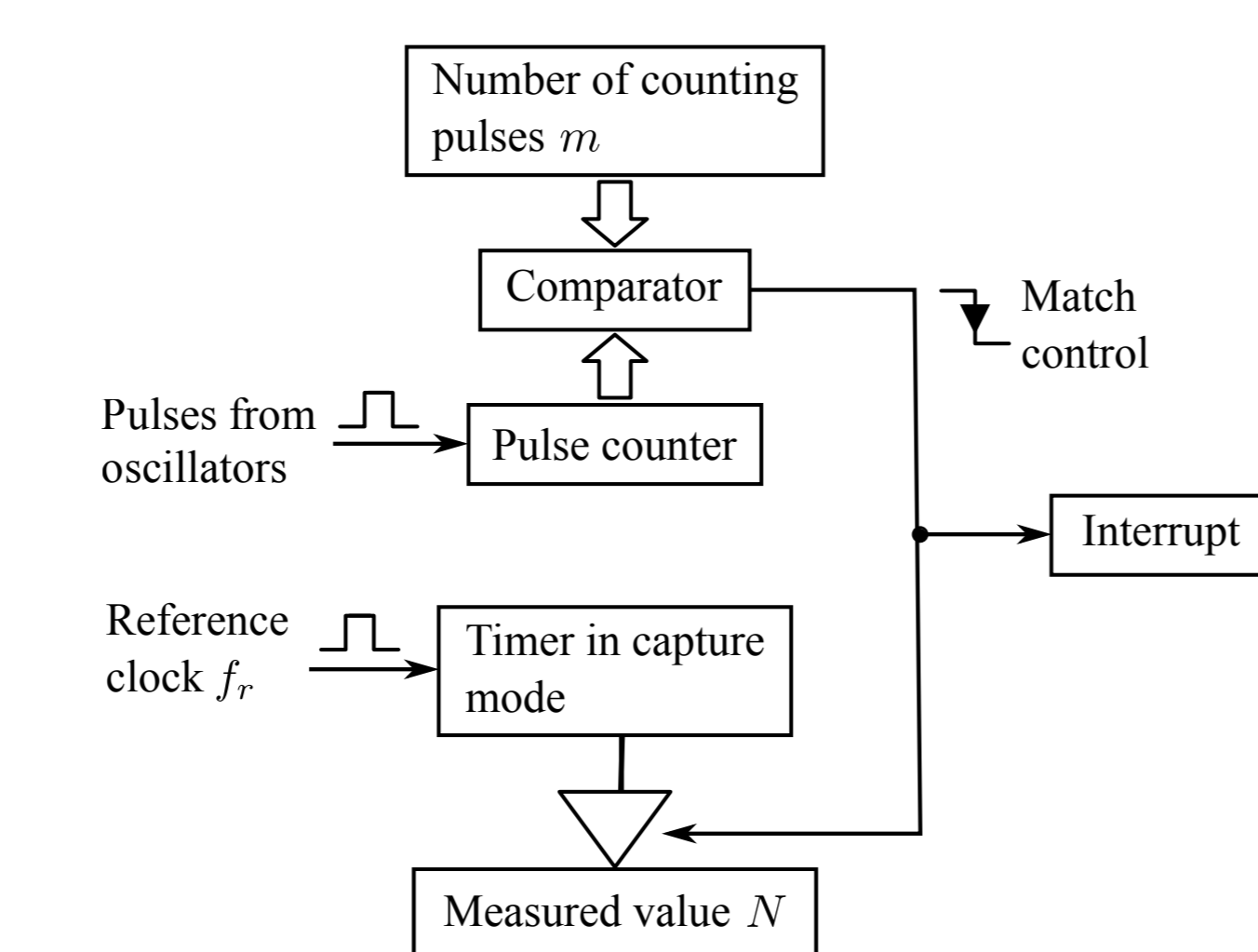


Figure 4

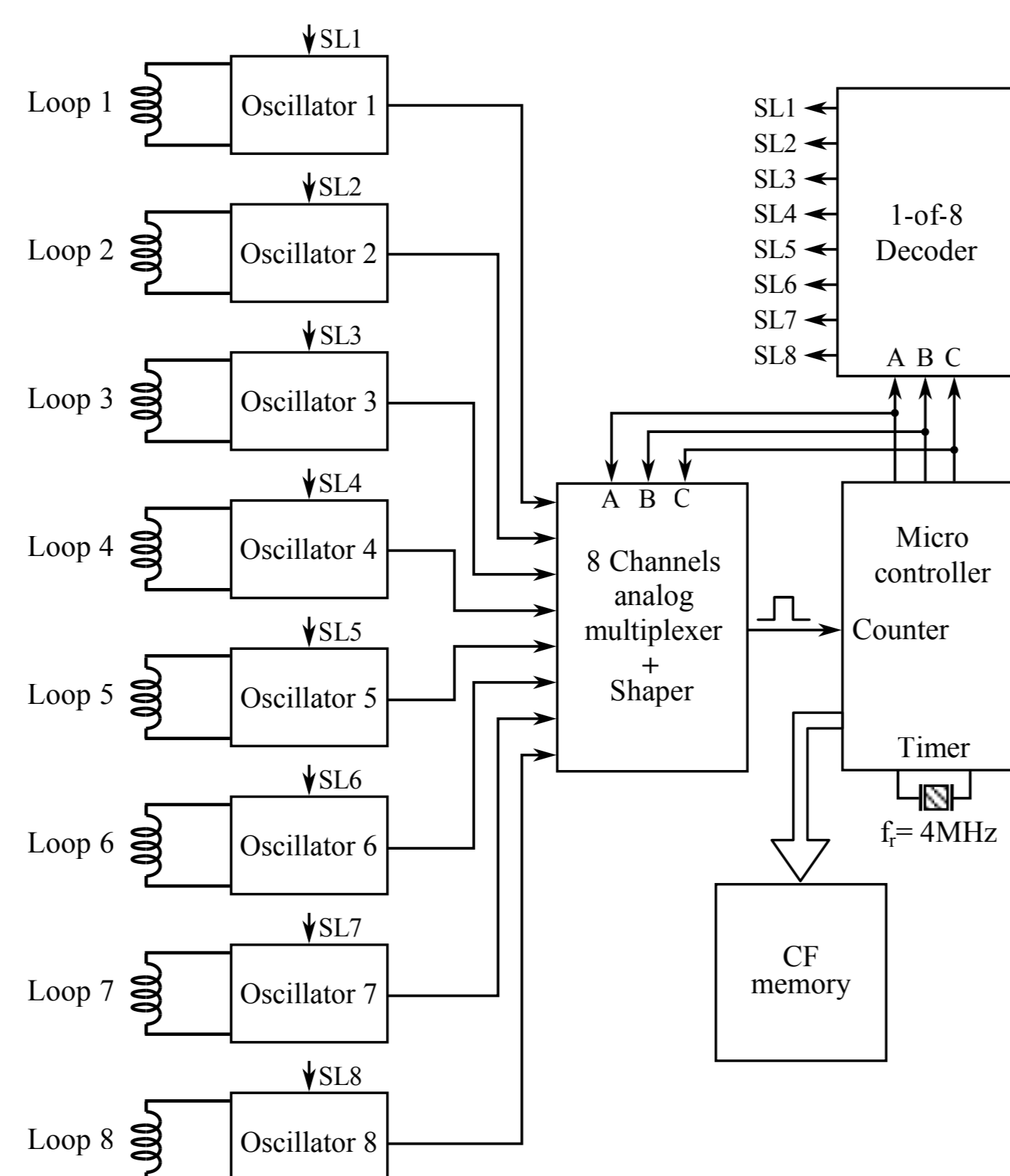


Figure 5

Fig. 6 shows a picture of the implemented hardware prototype. The left side of the board includes the eight oscillation circuits with multiplexing and a 16-pin connector for the connection of the eight inductive coils. The right side contains the micro controller and a Real-Time Clock (RTC) circuit with a lithium battery providing the date and time. The CF memory card used for the storage of the captured signatures can be seen at the bottom. One of the main advantages of the proposed system is that it can be implemented at a very low cost, thanks to its simplicity.

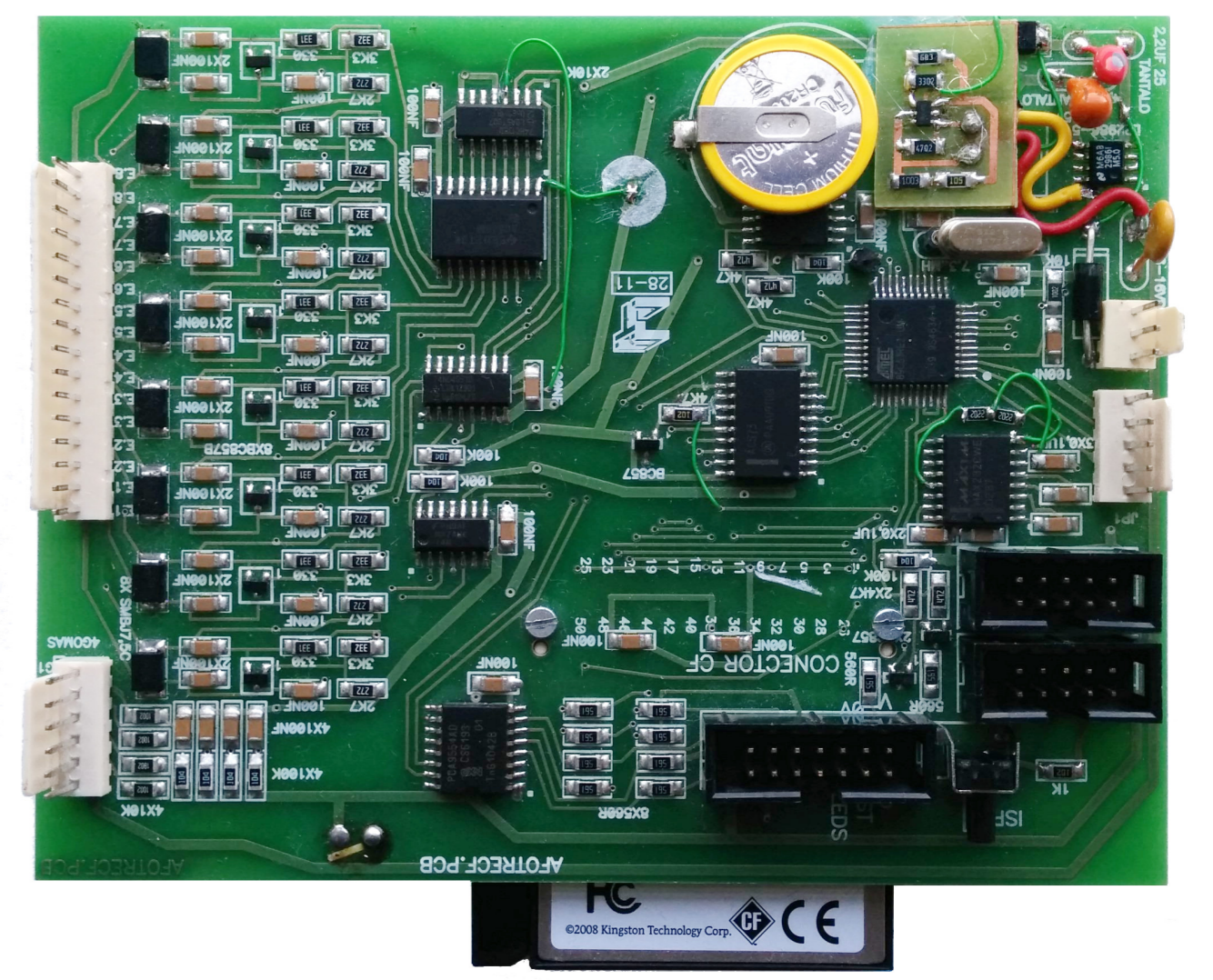


Figure 6

3 Classification

In order to perform the classification we first extract a descriptor \hat{p} from the captured signal. In this work we propose the use of a descriptor based on the first normalized local maximum of the DFT of the captured signal. This DFT descriptor has the advantage over other typical descriptors (such as speed or length) that it can be extracted from only one loop per lane, since it is independent of the speed of the vehicle.

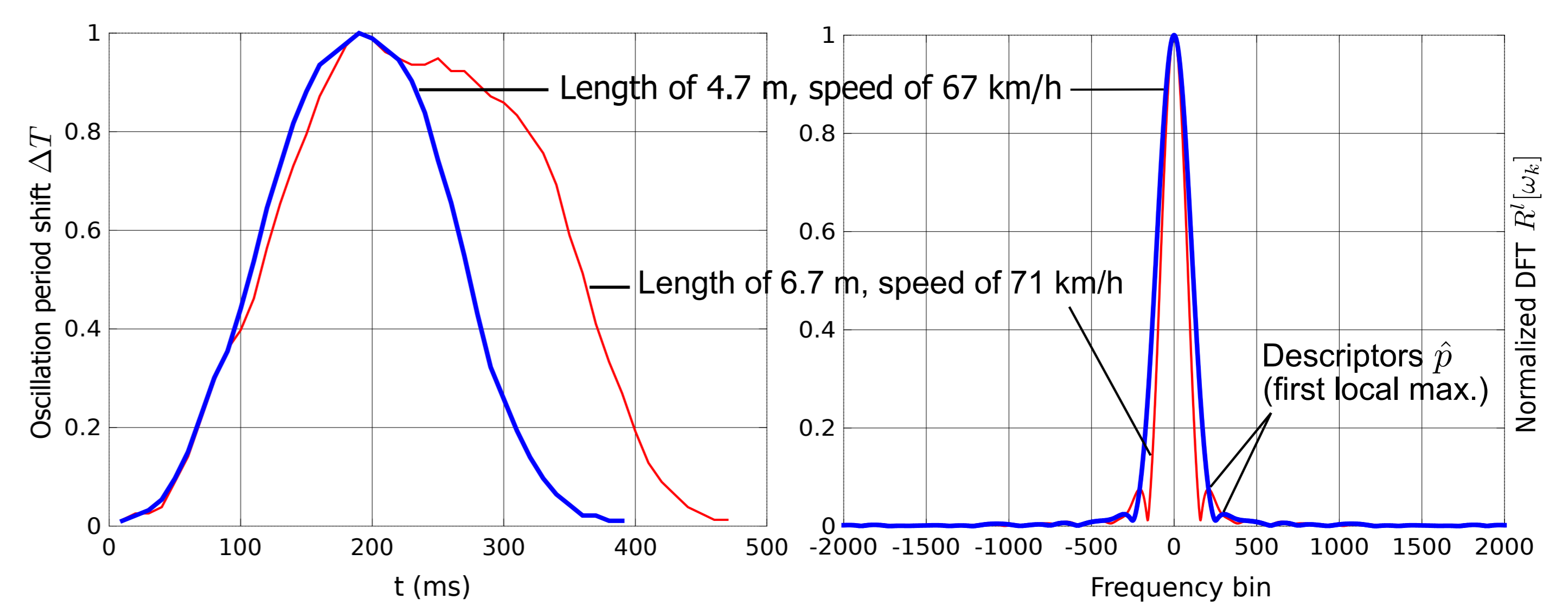


Figure 7

Figure 7 shows on the left the captured inductive signature of two vehicles: a car of 4.7m and a van of 6.7m. On the right, we can see the DFT of the captured inductive signals.

Using the descriptor extracted from each signature we can use a simple threshold-based method to decide between the desired classes. In this work we decide among three classes of vehicles: cars, vans or trucks.

$$\hat{p} \leq \epsilon_1 \rightarrow \text{Car}; \quad \epsilon_1 < \hat{p} \leq \epsilon_2 \rightarrow \text{Van}; \quad \hat{p} > \epsilon_2 \rightarrow \text{Truck},$$

The values of ϵ_1 and ϵ_2 must be determined in a training step.

4 Results

We capture inductive signatures on the AC-523 road (Ledoño-Meirama, Spain), and on the AC-415 road (Pastoriza-Arteixo, Spain). A picture of the AC-523 road location is shown in Fig. 8. The detector equipment was located inside the cabinet of the Río Anllóns station, also shown in the photo.

Since the road is two lanes wide (one for each direction) we placed four inductive loop sensors, two in each side of the road as shown in Figure 2.



Figure 8

In the training stage, we have considered the signatures captured in the AC-523 road on the loops 1 and 3. The value corresponding to the threshold ϵ_1 (0.06) is obtained when only cars and vans are considered, while the threshold value ϵ_2 (0.11) is obtained when only vans and trucks are computed.

Table 1 shows the error percentage for the classification of each type of vehicle. For the AC-523 road, the results in loops 1 and 3 correspond to the training phase.

	AC-523				AC-415			
	Cars	Vans	Trucks	Total	Cars	Vans	Trucks	Total
DFT, loops 1 and 3	1.62	31.15	4.76	4.18	2.35	18.99	21.52	4.75
DFT, loops 2 and 4	2.06	32.79	8.33	5.28	0.88	22.79	18.99	3.56

Table 1

Since car and van signatures are very similar, most classification errors are produced for vans but the DFT-based criterion proposed in this work leads to lower error percentages than others found in the literature based on estimating the length and speed of vehicles.