Embedded adaptive algorithm for multi-lanes-traffic inductive loop detecting system

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Abstract

This paper presents a design of an embedded multi-lanes-traffic monitoring system based on the use of multiple inductive loop detectors. By virtue of the embedded adaptive algorithm processor, the system has a capability to continuously adjust itself to overcome environmental variations which directly affect to the material characteristics and electronic circuits. As a result the system can effectively employ a low cost oscillator which is the key benefit of this design. In practical experiments on a three-lane road, the system presents very accurate vehicle counting results from all traffic conditions such as light, heavy and even obstructed traffic. The system can also detect vehicle moving in the middle of two lanes correctly.

Keywords: Embedded system, inductive loop detector, transportation

1. Introduction

Today traffic problem in big cities seems to grow and becomes quite serious since there are a big increasing number of vehicle on roads. Philosophy of the solution is basically how we can manage to flow all vehicles on the roads as fast and smooth as possible. The prime severe traffic spots are around all intersections where nearly all passing-by vehicles have to stop for a few minute and cause the flow rate to drop down. Nowadays in all major cities, there is a great demand on a very smart traffic control system to be custom designed and installed at all traffic intersections. There are many research groups in many countries working toward the most proper system for their cities. In doing so, the best approach is to maximize the flow rate by controlling all traffic lights in relating to the amount of vehicles passing through the intersections. Hence a reliable vehicle detecting tool [1]-[3] is the main requirement of the system. At present, there are three types of the vehicle detecting systems: 1) Underground level detectors such as inductive loop, and magnetic detectors; 2) Ground level detector such as pneumatic tube; 3) Overhead level detector such as video camera, microwave or radar, laser, infrared and ultrasonic detector. The overhead level detector type seems to gain more popular nowadays however they have a drawback on accuracy when the road is in a heavy traffic condition and other environmental effects such as temperature, dusty, raining and windy conditions. Ultrasonic vehicle detection in [4] presented an error of ±6%, while the pyroelectric [5] gave a maximum 21% error. The digital image processing technique [6] presented the error up to 10%. These referred techniques are then not suitable for using in heavy traffic condition. The pneumatic tube type gives a very accurate counting but it has a drawback on easily broken tube and can not classify vehicles of each lane. While those underground level detectors which are permanently installed underneath road surface have advantage on accuracy in counting with high capability in classifying vehicle of each lane and require less maintenance, however their characteristics are easily affected by the vast variation of temperature and humidity of the inner road materials. This paper then proposes a traffic vehicle detector using multiple inductive loops to classify vehicles of each lane separately. Embedded with an adaptive algorithm on PIC16F877 processor, the detector can continuously adjust the system to overcome the environmental variations such as temperature and humidity, giving a very accurate counting of vehicles at the speed range of 0~150 km. per hour. Hence a low cost oscillator can be effectively employed and reflecting the key issue of the design. Since all embedded inductive loops are connected to the central processing unit, the system can count vehicles without error although some vehicles move in the middle and through any two lanes. Practical experimental results from real road tests are given to confirm the capabilities.

2. System components

The proposed vehicle detecting system comprises three main building blocks; inductive loop for vehicle actuation, low cost oscillator circuit and embedded adaptive algorithm micro controller. As shown in Fig.1 the inductive loop is buried as conducting layer underneath road surface to form an inductance of which the value can be varied upon the magnetic flux changed by a crossing vehicle.

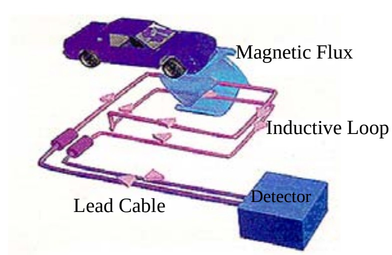


Fig.1 Inductive loop outline underneath road surface

Basically the inductance variation is actuated by an existence of vehicle above the inductive loop. The loop must then be designed to match with vehicle types it is needed to detect. The design parameters of the loop are given in (1).

$$L = \frac{P(t^2 + t)}{4} \tag{1}$$

where L = Inductance (micro Henry)
P = Perimeter (Feet)
t = The number of turns

and the sensitivity of the inductive loop [7], [8] can be derived to

$$A \approx \frac{V_S}{L_S \times V_H} \tag{2}$$

where A is the sensitivity of the inductive loop to the detected vehicle; V_S denotes the length of the detected vehicle; L_S is the length of the inductive loop; V_H responds to the height of the detected vehicle. The inductive loop is then connected to a low cost oscillator circuit as shown in Fig.2 where the inductive loop is represented as L_3. The oscillator generates a signal with a frequency given by (3)

$$\omega_O \approx \frac{1}{L_3}\left(\frac{C_1 + C_2}{C_1 C_2} + \frac{L_3}{C_1 C_2 r_o\left(r_{bb} + r_{be}\right)}\right)$$

$$fo = \frac{1}{2\pi\sqrt{L_3 \dfrac{C_1 C_2}{C_1 + C_2}}} \tag{3}$$

where r_{bb} and r_{be} are the small parameter of the transistor, then the oscillating condition can be derived in (4).

$$g_m \approx \omega_o^2 C_1 C_2 L_3 \left(\frac{R_3}{L_3} + \frac{1}{C_1\left(r_{bb} + r_{be}\right)} + \frac{1}{C_1 r_o}\right) \tag{4}$$

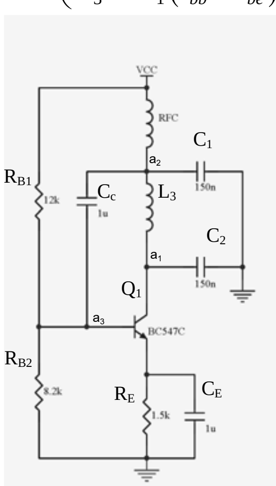


Fig.2 Low cost oscillator

In this design, we have set the design parameters of the loop to 6×6 square Feet having the inductance in the range of 50μH – 1mH which corresponds to the oscillation frequency in the range of 1kHz – 100kHz. When a vehicle passes across the inductive loop the signal frequency is varied accordingly. The variation of the oscillation signal is monitored by the embedded system to determine the counting and other various information of the vehicle such as the size and speed range of the car. As the aforementioned that the use of low cost oscillator is the key issue of the design here, we express that an expensive high quality oscillator can not be employed alone without the digital assistance anyway since there is such a vast variation of the environment effects in this applications. Then if there is a capable digital assistance part in the system, only a low cost oscillator like in Fig.2 is enough to allow the embedded processor to operate the system efficiently.

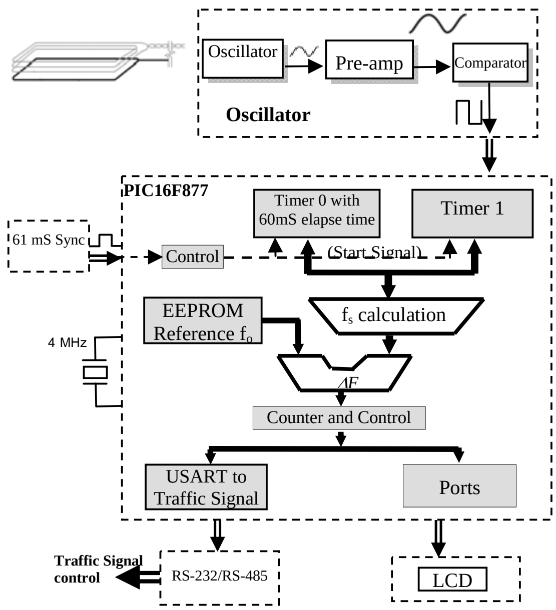


Fig.3 Inductive loop detecting system diagram

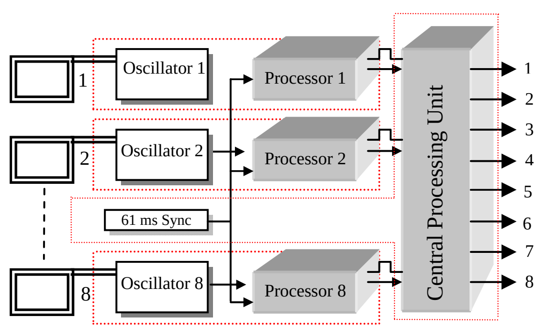


Fig.4 System diagram for 8-lanes traffic

The embedded micro controller part is shown in Fig.3 as part of the inductive loop detecting system which is employed in each traffic lane. Then all the loop detecting parts of all traffic lanes will be connected to the central processing unit which normally situates at the junction box of a traffic light intersection. The main task to the local-lane loop detectors is to detect an existence of a vehicle moving through the lane. However, since there are some vehicles moving across two consecutive lanes the central processing unit performs the task to determine if the vehicle existing in the two lanes is the same one or not. The counting results are then solid and respond to the actual number of vehicle on the road.

3. Adaptive algorithm

The system is designed to detect vehicle at speed in the range of 0-150 km per hour which corresponds to the counting of the oscillation pulse within 60mS sampling window. In other words, the oscillation signal originated by the oscillator as a result of the vehicle actuation will be monitored in every 60mS.

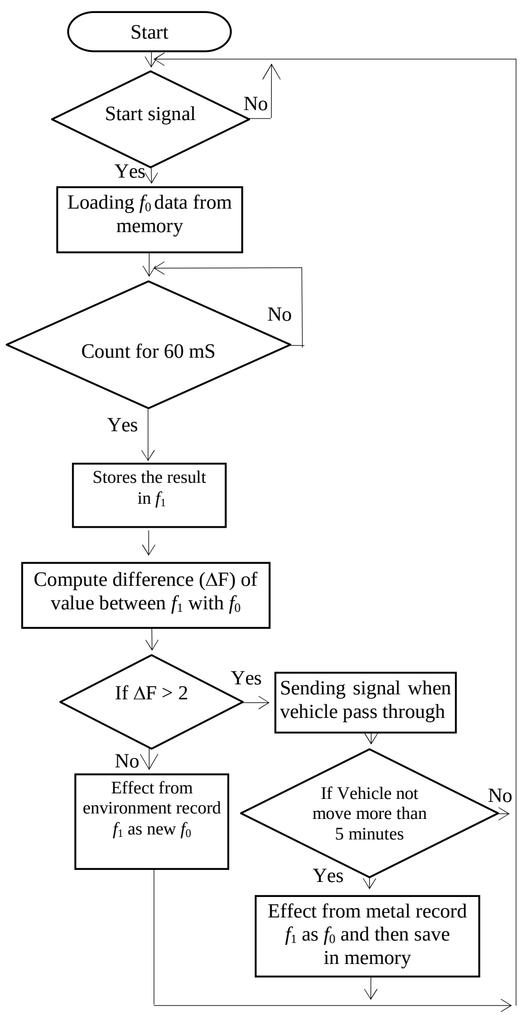


Fig.5 Flow chart of local-lane loop detector

From fig.5, it is seen that the pulse counting of each 60mS will be saved as the reference frequency which will be used to compare with the count result of the next consecutive 60mS. If there is a significant change in the count between the two consecutive sampling windows, the detector determine that there is a vehicle crossing the loop. Regarding to the variation of the oscillation frequency as a result of the environment and a parking car on the loop of the leftmost lane, the detector must be able to detect the situations and then update the reference count in order to be compared with the sampling window count effectively. From the environment effect, the signal frequency normally changes slowly within much less than 1 percent in the range of 60mS and between the consecutive sampling windows. However, the reference count can be as high as 30 percents different between the morning, the noon and the evening time. Regarding to a parking vehicle above a loop unintentionally, the signal frequency change dramatically at the first few sampling windows but the slope of the change will come to zero soon after a few windows. The detector must detect this situation and update the reference counting number in order that there is no repetitive count on the same vehicle mistakenly.

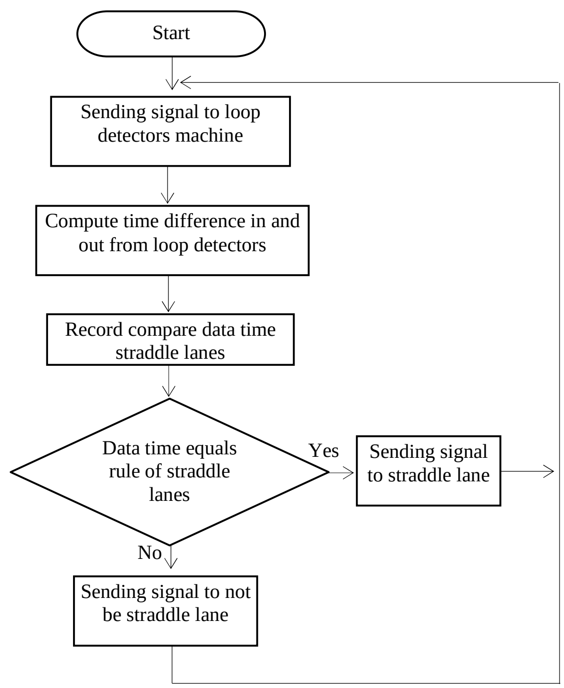


Fig.6 Flow chart of the central processing unit to detect straddle vehicles

From Fig.6, it is the flowchart of the central processing unit which monitors signal different from all detector loops to determine if there is a mistaken count occurring when one vehicle moves across to two consecutive lanes unintentionally. The central processing unit must be able to detect and collect a correct count only. Since all the local loop start counting at the same time stamp as a result of a synchronous signal on every 61mS, there is less chance to have two vehicles passing through two consecutive lanes at the same time stamp. With this proposed system, the detector can record the time stamps of when the cars coming in and out of the loop. The error from the wrong counting can be most minimized. The timing of the straddle case is shown in Fig.7

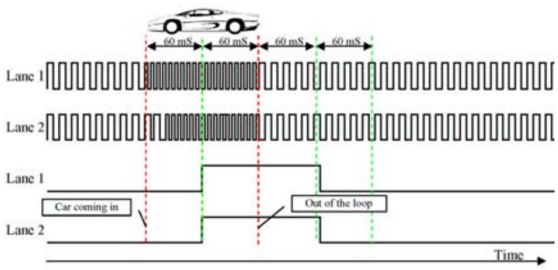
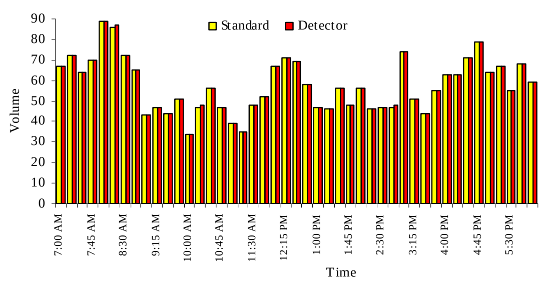
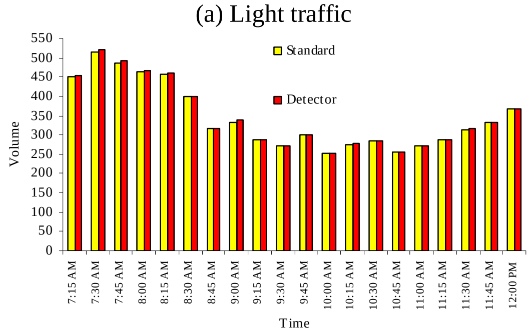


Fig.7 Timing of the straddle case between two lanes

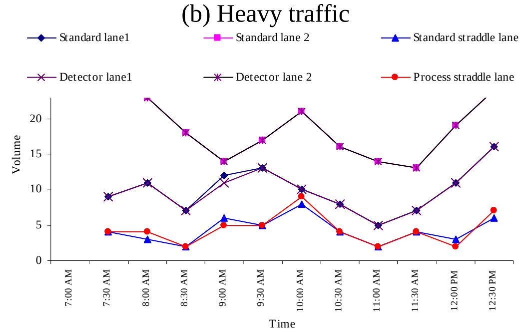
4. En-road experimental results



(a) Light traffic



(b) Heavy traffic



(c) Straddle case

Fig.8 Practical experimental results

From Fig.8, we have performed practical experiments on a real highway in different time and traffic conditions. It is seen that the system delivers very accurate results especially in the straddle case.

5. Conclusion

We have presented a traffic vehicle detector using multiple inductive loops to classify vehicles of each lane separately. Embedded with an adaptive algorithm on PIC16F877 processor, the detector can continuously adjust the system to overcome the environmental variations such as temperature and humidity, giving a very accurate counting of vehicles at the speed range of 0~150 km. per hour. Hence a low cost oscillator can be effectively employed and reflecting the key issue of the design. Since all embedded inductive loops are connected to the central processing unit, the system can count vehicles without error although some vehicles move in the middle and through any two lanes. Practical experimental results from real road tests are given to confirm the capabilities. The system is very useful for any cities that need meaningful traffic data for their efficient planning and successful implementation. This system does not only perform normal vehicle counting but can identify the counting of each traffic lane so that we can analyze driving behavior for future road and intersection planning effectively.

6. References

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