Some Aspects of Speed Recording in a Vehicle Functional Parameter Recorder

Laurenţiu Dimitriu[1], Liliana Vornicu[2], Cristian Aghion[1]

[1,2,3] "Gh. Asachi"Technical University of Iaşi, Faculty of Electronics and Telecommunications

B-dul Carol I no. 11, Iaşi, 700596 Romania

dimitriu@etc.tuiasi.ro

lvornicu@etc.tuiasi.ro

aghion@etc.tuiasi.ro

***Abstract*—In our paper some aspects of speed recording in a vehicle functional parameter recorder (FPR) are presented. The traffic problems impose to find new solutions to improve the safety of vehicles, and if unfortunately an accident has occurred, it is very important to understand its dynamic and to establish the responsibilities.**

I. Introduction

The using of vehicle functional parameter recorders (FPRs) becomes a feature of new generations of ground vehicles. It is a part of IHVS (*Intelligent Highway Vehicle System*) concept and the approach is based on progress in technologies of VLSI circuits and memories.

It appears as a development of Event Data Logging (EDL) (or Event Data Recorder – EDR) used in some airbag controllers. These controllers do more than just trigger the airbags; they also log the speed and a range of other driving actions. EDRs were first used in automobiles in the 1970s, when airbags first came out. Automobile manufacturers have been using the data ever since to collect real world crash data, which they used, for example, in modifying airbag designs. The data is also being used in the medical field to compare injury forces acting on the body and by insurance companies with regard to claims. The implications - not only for drivers but also for insurance companies, the police, and car rental companies - are profound. In USA, the potential benefits of Event Data Logging (EDL) have also resulted in strong Government support for adopting universal standards for such systems. Taking into consideration the strong influence of legislation on carmakers, it's only a matter of time before all cars have Event Data Logging recorded in a standard format that can be easily read. The benefits identified for Event Data Recorders (EDR) using are significant [1]:

- Real Time Assistance: the use of EDR data in conjunction with Automatic Collision Notification systems would aid in quickly locating crashes and dispatching emergency personnel with better crash information in advance;
- Law Enforcement: obtaining impartial EDR data from a collision would help in more accurately determining the facts surrounding the incident;
- Government Initiatives: the collection of EDR data would enable governments to introduce effective initiatives to help reduce fatalities, injuries and property loss;
- Vehicle Design: EDRs allow manufacturers to collect accurate data to monitor system performance and improve vehicle design;
- Highway Design: the use of EDR data can assist in assessing highway roadside safety and managing road systems;
- Insurance/Legal: Additional objective data provided by EDRs advance quicker and fairer resolution of insurance and liability issues;
- Research: EDR data could provide objective data for researching driver behavior and performance, as well as other research related topics;
- Owners/Drivers: EDRs can help fleet owners and drivers monitor vehicle and driver performance, to ensure the safe and efficient movement of people and cargo.

Another aspect considered in our paper is concerning the use of digital tachograph technology. A digital tachograph is an electronic system for recording driving and rests times for drivers and co-drivers of commercial vehicles. Vehicle speed, distance traveled and other system-related parameters are also logged. The introduction of digital tachograph has become mandatory within the EU Community from May 2006 [2], [3]. [4].

In order to support drivers not to exceed the posted speed limits and to choose an appropriate highest situational speed in bad weather conditions, for example, Intelligent Speed Adaptation (ISA) systems are developed. Studies conducted in different countries illustrate the remarkable traffic safety benefits of ISA [5]. In trials the user acceptance of various systems has been high and acceptance has increased along with use of the system in practice. Approximately 60 – 75% of users would accept ISA in their own cars.

Based on speed and other vehicle parameters recording, it is possible to monitor a vehicle driver performance [6].

Is described also a method for determining a sideslip angle of terrestrial vehicle that moves on wheels using a Global Positioning System receiver. This one measures the horizontal velocity of the vehicle as well as its altitude. The sideslip angle of the vehicle is obtained from these measurements [7].

A system and method are also presented for monitoring motor vehicle movement parameters, such as speed, location and acceleration, using a Global Positioning System (GPS) [8].

II. Vehicle Speed Measuring Principle

The information on vehicle speed could be obtained from a pulse sensor. In the Figure 1 a wheel speed measuring system principle is presented. Using a Hall pulse sensor the signal level is not depending on wheel speed, an important aspect in low speed measurement. The toothed ring is rigid coupled to the wheel and consequently has the same rotation speed. A solution is to use a wheel speed sensor from antiskid brake system (ABS). In the Figure 2 is shown the waveform of the delivered signal from wheel speed measuring system. It is easy to measure the wheel speed, and based on it the vehicle speed, by using timers / counters from a microcontroller system. . In fact it is measured a period sample, denoted by t_m in the Figure 2. The data from the timer / counter is stored in an adequate memory and could be used later to calculate the vehicle speed, taking into consideration some constructive parameters.

The system measures the time value t_m, having, as in (1), the following dependence on period of rotation of the vehicle wheel:

$$t_m = T / p \qquad (1)$$

where:
T – wheel revolution period;
p – teeth number of toothed ring.

The t_m time measuring is done using a time base (e.g. having a frequency of 1 MHz, T_{ck} = 1 µs clock pulse) and a 16 bits counter (2^{16} counting capacity – 65535 µs maximum time interval for t_m). The counting result will be a number N_m, as is shown in (2):

$$N_m = t_m / T_{ck} \qquad (2)$$

We can write (3);

$$t_m = N_m \cdot T_{ck} \qquad (3)$$

From (1) and (3) it results (4):

$$N_m \cdot T_{ck} = \frac{T}{p}, \quad T = N_m \cdot p \cdot T_{ck} \qquad (4)$$

The vehicle speed could be calculated based on N_m value, as will be shown in the following. Consequently, these values are stored in an adequate memory device.

If D is the wheel diameter, the vehicle speed v could be determined taking into consideration the wheel revolution frequency f and wheel diameter (5), (6):

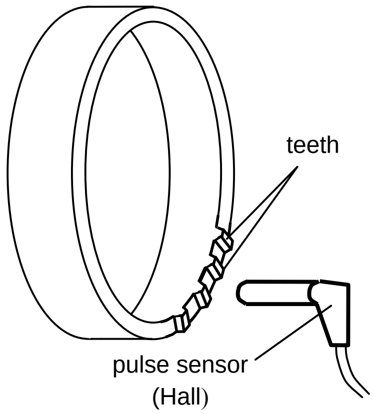

Figure 1. Wheel speed measuring system

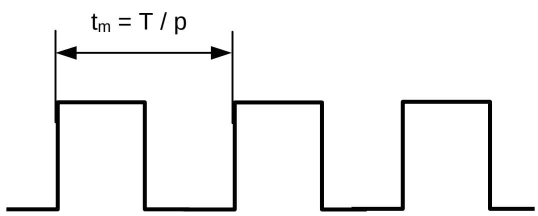

Figure 2. Waveform of signal delivered by wheel speed measuring system

$$f = \frac{1}{T} = \frac{1}{N_m \cdot p \cdot T_{ck}} \qquad (5)$$

$$v = 2 \cdot \pi \cdot D \cdot f = \frac{2 \cdot \pi \cdot D}{N_m \cdot p \cdot T_{ck}} \qquad (6)$$

The vehicle speed, as in (6), is corresponding to the situation when the brake is not acted (and there is not a wheel slip s). When the brake is working, the vehicle speed in this situation, v_b, is greater then the speed obtained using (6), as in (7):

$$v_b = \frac{v}{1 - s} \qquad (7)$$

For an ABS fitted automobile, the slip value is above 0.2.

A. *An example of vehicle speed determination*

We want to calculate the speed of an ABS fitted automobile, at the beginning of a braking sequence (the wheel is not slipping). The automobile uses 15 inches wheels and 195/40 tires. The number of teeth of toothed ring p from wheel speed sensor is 16. The system has stored in the memory a value N_m = 7549 for the moment of brake beginning. The clock period is T_{ck} = 1 µs. The wheel diameter [9] is (8):

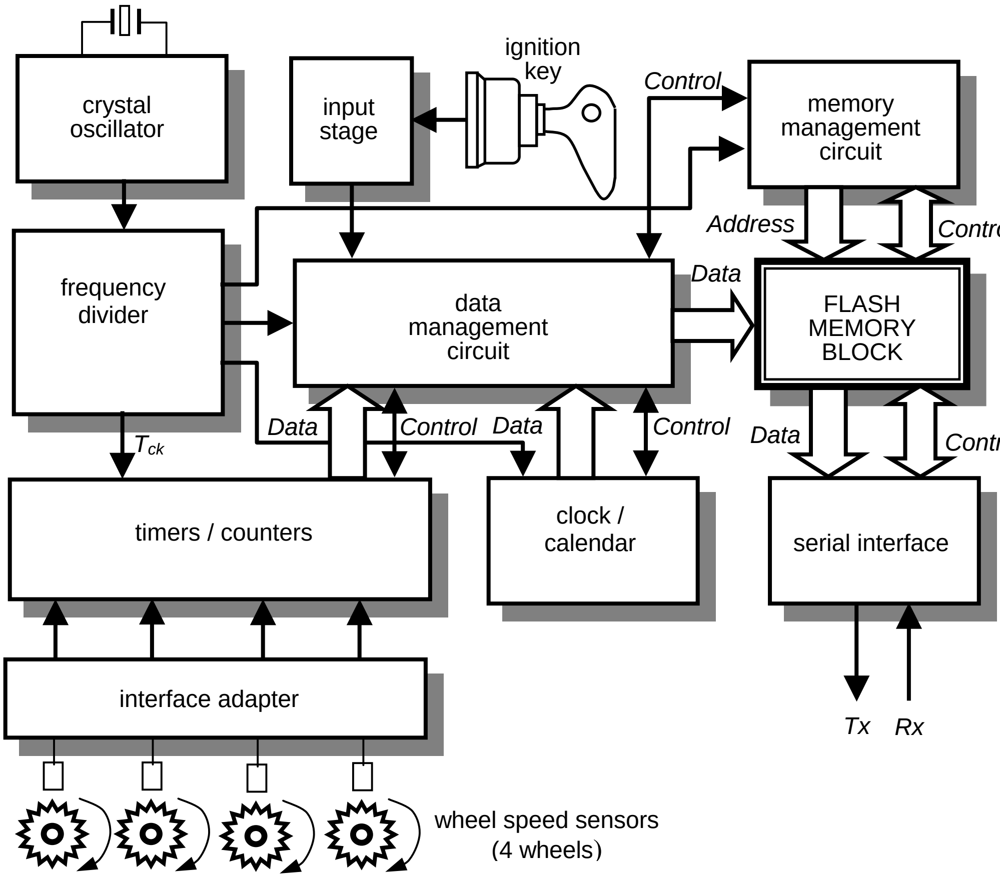

Figure 3. Block diagram of the vehicle speed recording system

$$D = 15 \cdot 25.4 + 0.4 \cdot 195 = 459 \ mm = 0.459 \ m \quad (8)$$

The vehicle speed is (9):

$$v = 2 \cdot \pi \cdot D \cdot f = \frac{2 \cdot \pi \cdot D}{N_m \cdot p \cdot T_{ck}} = \frac{2 \cdot \pi \cdot 0{,}459}{7549 \cdot 16 \cdot 10^{-6}} = 24.165 \ m/s \quad (9)$$

This value corresponds to a vehicle speed of 86.995 km/h.

If we want a maximum measurement error of 2%, it results that the minimum time interval corresponding to 50 clock pulses (quantifying error criterion), respectively 50 μs. The maximum vehicle speed that can be measured with the imposed error is (10):

$$v_{\max} = v \cdot \frac{7549}{50} \approx 87 \cdot 150.98 = 13135.26 \ km/h \quad (10)$$

Minimum speed threshold that can be measured (11) is fixed by counting capacity limited to 16 bits (65536 quanta):

$$v_{\min} = v \cdot \frac{7549}{65536} \approx 87 \cdot 0.1152 = 10.02 \ km/h \quad (11)$$

Evidently, these extreme values could be modified using another clock period for 16 bit counters. If it is used T_{ck} = 50 μs, the two extreme values calculated above (10), (11) become (12):

$$v_{\max} = 262.7 \text{ km/h}, \ v_{\min} = 0.\ 2 \text{ km/h} \quad (12)$$

A maximum speed of 525 km/h could be measured with 4% error using a pulse clock period T_{ck} = 50 μs, (in this situation 25 pulses are counted).

III. BLOCK DIAGRAM OF THE SISTEM

To have an exactly frame of vehicle movement at an instance, the system must record time data (day, hour, minute and second when ignition was switched "ON" and "OFF", time marker for measured wheel speed samples). In this approach, could be "re-build", from speed point of view, whole vehicle travel from the moment when ignition is switched on until the ignition is switched off.

In the Figure 3 is presented the block diagram for the vehicle speed information recording in a vehicle functional parameter recorder.

There are 4 wheel speed sensors used (one for each automobile wheel). An interface adapter assures the voltage level compatibility for signals controlling four 16 bit counters / timers. These ones measure the period samples (t_m) used to calculate the vehicle speed. The clock period for counting (T_{ck}) is obtained in a frequency divider, which receives a reference time signal delivered by a crystal oscillator. The data resulted from the four timers / counters are transmitted to a data management circuit that also receives data from a clock / calendar section. These two categories of data are stored in the flash memory block with a sample ratio controlled by data management circuit and transfer controlled by a memory management circuit. The last one assures *Addresses* and *Control* signals used to log data from data management circuit into flash memory block. The start of data logging is when the ignition is switched on from ignition key. The end of logging is pointed when the ignition is switched off. An input stage delivers an adequate signal to memory management circuit when the ignition key is acted. The logged data could be extracted to a computer from the flash memory block via a serial interface.

A. Effect of memory capacity

Data could be stored in a standard PC format allowing fast transfer of data to a PC. The file format is one that can be loaded directly into adequate software or imported into in a standard powerful tool e.g. Excel, to analyze the information. Evidently, the amount of logged data is depending on the flash memory capacity.

Let assume that the system uses a 16 GB flash memory. This capacity is assured in a 56-nm process technology. The 16Gb is the highest density single-chip NAND flash memory yet achieved [10].

If the sample ratio is 100 Hz (a sample / 10 ms) and whole data logged in the functional parameter recorder (not only wheel speed data – 8 bytes for the four wheels and time information) is e.g. 100 bytes long for a sample, it results 1,600,000 seconds of recording time. This means 444.44 hours. In this time, at an average speed of 60 km/h, a vehicle travels about 26,666 km. Reading the data logged into the flash memory it is possible to obtain very important information about the behavior of the vehicle and driver.

B. Other possible developments

The overall information about the vehicle travel could be obtained by an optimal choosing of parameters logged. If is used a Global Positioning System (GPS), is possible to record information on position and Coordinated Universal Time (UTC). Analyzing this information is possible to calculate with high accuracy the actual vehicle speed and to determine e.g. the map road, the slip of the four wheels during braking, as well as if there was a pressure of tire inflation problem.

IV. Privacy Implications

While road safety researchers highlight the potential benefits of EDRs or FPRs, many drivers and vehicle manufacturers are concerned about the privacy implications. In USA, the US Federal Motor Carrier Safety Administration has stated that the following standards should apply to controlling access to EDR data [1]:

- The vehicle's owner should also own the EDR data;
- Only the vehicle's owner, or another party having the owner's permission, may access the EDR data. Exceptions would include instances where a law enforcement official has a warrant for a crash investigation;
- One method of assuring that only owners have access is through the use of an EDR password;
- The storage and retrieval of EDR data must protect the privacy rights of the individual in accordance with law.

Certainly, there needs to be more public debate about the privacy issues involved with EDR and FPR.

There are appeals concerning admissibility in justice of the “black box” (EDR) speed recording, e.g. a case when it was used data retrieved by police after a fatal crash [11]. In the above-mentioned case, has been used a study concluded that the EDR data overestimated vehicle speeds by a mere 1.5 km/h at low speeds and by 3.7 km/h at high speeds [12].

V. Conclusions

There are still technical and legislative obstacles as regards to implementing the most EDR and FPR systems. International co-operation of research institutions, automotive industry and road administrations as well as discussion on political and legislative level is essential for their implementation. In our paper we suggest only a solution for a part of technical problem.

References

[1] J. Egar , ”Logging Your Every Driving Moment”, Silicon Chip – Online Magazine, Silicon Chip Publications Pty Ltd & Web Publications Pty Limited, http://www.siliconchip.com.au/cms/A_30802/article.html, Published: 17 November 2003, Issue 182.

[2] * * *, Council Regulation (EEC) No. 3821/85[2] Council Regulation (EEC) No. 3821/85 on recording equipment in road transport, 20 December 1985, http://europa.eu.int/eur-lex/en/index.html

[3] * * *, Council Regulation (EEC) No. 2135/98 amending Regulation (EEC) No 3821/85 on recording equipment in road transport and Directive 88/599/EEC concerning the application of Regulations (EEC) No 3820/84 and (EEC) No 3821/85, 24 September 1998, http://europa.eu.int/eur-lex/en/index.html

[4] * * *, Annex 1360/02 of Council Regulation (EEC) No. 2135/98, Official Journal of the European Communities, 5.8.2002.

[5] [ISA] H. Peltola, J. Tapio, R. Rajamäki, “Intelligent Speed Adaptation (ISA) - recording ISA in Finland”, ViaNordica 2004, pp. 1-9, http://www.rws-avv.nl/prosper/ISA_NVF2004_Peltola.pdf.

[6] J. Ousborne, “Vehicle Driver Performance Monitoring System”, United States Patent, Pat. No.: 5,499,182, Date of Patent: Mar. 12, 1996.

[7] D.M. Bevly, J. C. Gerdes, “Determination and Control of Vehicle Sideslip using GPS”, United States Patent, Pat. No.: 6,681,180 B2, Date of Patent: Jan. 20, 2004.

[8] A. J. Vogelsang, “Portable Speed-Recording Device for Motor Vehicles”, US Patent Office, Patent Application Publication, Pub. No.: US 2004/0143378A1, Pub. Date: Jul. 22, 2004.

[9] * * *, *BOSCH Automotive Handbook*, Third Edition, Stuttgart, 1993

[10] * * *, “Toshiba to Launch 56-Nanometer, 16-Gigabit NAND Flash Memory”, 24 January, 2007 http://www.toshiba.co.jp/about/press/2007_01/pr2401.htm

[11] * * *, CASE NO. 4D03-2043, In the District Court of Appeal of the State of Florida, Fourth District, January term 2005, http://www.harristechnical.com/downloads/4DCA1.pdf

[12] J. M. Lawrence, C. C. Wilkinson , B. E. Heinrichs, “ The Accuracy of Pre-Crash Speed Captured By Event Data Recorders”, SAE 2003 World Congress & Exhibition, Detroit, MI, USA, Session: Accident Reconstruction (Part 3 & 4 of 4), SAE Technical Papers Document Number: 2003-01-0889, March 2003.