SELECTED VEHICLE MONITORING PROBLEMS WITH THE "e-Call" SYSTEM TAKEN AS AN EXAMPLE

BOGUSŁAW PIJANOWSKI[1], DARIUSZ ŻARDECKI[2]

Automotive Industry Institute, Military University of Technology

Summary

The paper is dedicated to the problems of monitoring of road vehicles, especially "intelligent" motor vehicles provided with an e-Call system (a safety system with an automatic accident notification function). Following the introduction into the vehicle monitoring issues and presentation in outline of a concept of the e-Call system, supplemented with a list of major relevant documents and draft international and national standards, in particular those concerning the so-called Minimum Set of Data (MSD), the paper in its subsequent part has been focused on the methods of automation of the identification and assessment of effects of vehicle collision accidents. Two methods related to the vital functions of vehicle occupants have been considered: one based on signals obtained from deceleration sensors and another one where signals from pulse sensors and camera images would be used. The possibilities of using the HIC (Head Injury Criterion) indicator by correlating its values with values of the biomedical indicator AIS (Abbreviated Injury Scale), which numerically defines the injury severity degree, have been analysed. Results of tests carried out at the Automotive Industry Institute (PIMOT) with the use of both a crash test stand and computer simulation have been cited. The tests were performed on a Suzuki Swift passenger car.

Keywords: intelligent transportation systems; intelligent car; motor vehicle safety system; e-Call; MSD package; road accident identification and assessment, crash test results

1. Introduction

When the Global System for Mobile Communication (GSM) came into existence and when it was incorporated into the satellite communication system, the monitoring of stationary objects without territorial limitations became technically possible. The popularization of the Global Positioning System (GPS) has enabled the extending of these possibilities to mobile objects, especially road vehicles.

Vehicle monitoring systems are based on specialized monitoring stations where data obtained from remote measurements are immediately collected for 24 hours a day. Examples may be the antitheft vehicle protection systems or fleet monitoring systems (the

[1] Automotive Industry Institute (PIMOT), 55 Jagiellońska Street, 03-301 Warsaw, e mail: b.pijanowski@pimot.org.pl, ph. +48 22 777 70 15

[2] Military University of Technology (WAT), Faculty of Mechanical Engineering, e-mail: dzardecki@wat.edu.pl

latter being supplemented with functions of the on line reading of some information about motion parameters, stops, fuel consumption, cargo mass, etc.). The monitoring systems are used not only for road vehicles but also for construction or road-making machines that are often kept for a long time on building sites.

In the road vehicle monitoring systems, a special role is played by motor vehicle safety systems (MVSS) [7, 9.4] with a function referred to as e-Call (Emergency Call), which is used for automatic accident notification.

According to statistical data, about 1.3 million accidents annually occur on roads in the European Union, with about 43 000 killed and about 1.7 million injured [1]. The widespread use of e-Call systems in vehicles is expected to bring significant benefits, which may be categorized as:

- Social (less accidents with fatalities caused by lack of immediate help; improved traffic safety after the accident thanks to faster securing of the scene of accident, as the time of reaction of the rescue service to accident notification will be reduced by about 40 to 50%); and
- Economic (thanks to about 15% reduction in the losses incurred in result of road accidents, as the losses include the costs of medical treatment, sick leaves, damages, administration, civil, and criminal proceedings, repairs, etc.).

No wonder, therefore, that the initiative to introduce a system automatically activated after the occurrence of a road incident that would cause a specific degree of nuisance met with support of many institutions in the European Union. So far, the "e-Call memorandum" has been signed by 15 EU member countries: Austria, Cyprus, The Czech Republic, Estonia, Finland, Germany, Greece, Italy, Lithuania, Portugal, Slovakia, Slovenia, Spain, The Netherlands, and Sweden, and by three countries from outside of the EU, i.e. Iceland, Norway, and Switzerland. Other EU member countries, i.e. Belgium, Bulgaria, Hungary, Luxemburg, Romania, and Poland have expressed their support for this initiative and their will to sign a memorandum of agreement. This system is to be implemented in the European Union in 2014÷2015 and to be popularized within the next ten or fifteen years. GSM Europe, an association representing European operators of cellular telephony networks, has established a working group for developing a strategy of implementing the e-Call system in Europe.

From the point of view of telecommunication network operators, the service in the e-Call system is a special extension of the "alarm telephony" service, commonly offered in the EU and using the emergency telephone number "112," with a user location function known under the symbol "E112." An important development of the e-Call system in relation to the E112 one consists in more comprehensive specifying of the data automatically sent to the monitoring centre, thanks to which not only the fact that an accident took place but also the scale of the accident may be notified. This is possible thanks to numerous sensors, which already now make up the so-called "intelligent vehicle." The e-Call system is consistent with the concept of Intelligent Transportation Systems (ITS) [9.1].

The purpose of this study is to introduce the reader into the issues of motor vehicle safety systems with the e-Call function, especially into selected problems related to the relevant standards and to the collision effects assessment methods that would support the automation of accident notification.

In consideration of editorial limitations, ad hoc references to publications have been made instead of providing a separate review of the reference literature.

This study was carried out within a research project No. N N509 573239 "Development and testing of a car safety system within the structure of an 'intelligent vehicle'" sponsored by the National Centre for Research and Development.

2. The concept and standards related to the e-Call system

The basic principles of operation of the e-Call system may be described as follows, according to the relevant Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions [2]:

- When a road accident occurs, a telephone connection with the monitoring centre is automatically established, based on information collected from in-vehicle sensors, to call for help;
- The incident parameters coded in the system and recognized as indicating an accident have an impact on the activation of the telephone call to the emergency number 112;
- The connection with the emergency number simultaneously enables the generation of an alarm message automatically sent to the telephone network and the establishing of a voice call;
- The automatic alarm message consists of a so-called Minimum Set of Data (MSD), sent in the form of an SMS providing the most important information about the accident, such as time, location, and driving direction (according to precise data obtained from the satellite system), Vehicle Identification Number (VIN) of the vehicle, and additional information (sourced from the in-vehicle sensors);
- The voice connection can also be activated manually;
- The Mobile Network Operator (MNO) is able to distinguish an "ordinary" 112 telephone call from one generated by an automatically operating in-vehicle communication module by the so-called "e-Call flag";
- The network operator routes the call to a Public Safety Answering Point (PSAP);
- The MNOs should handle the e-Calls like any other 112 emergency calls. They must activate the "e-Call flag" discriminating system in their networks, thanks to which the e-Calls can be identified and routed to the most appropriate PSAP as defined by the national authorities;

– The PSAP operator will receive both the voice call and the MSD message;

– The information provided by the MSD will be decoded and displayed in the PSAP operator screen (the location and driving direction of the vehicle can be shown in a Geographic Information System);

– The PSAP operator will be able to hear what is happening in the vehicle and talk with the vehicle occupants (the possibility of obtaining information during the telephone talk should help the operator to ascertain which emergency services such as ambulance, firemen, or police are needed at the accident scene and to forward rapidly the notification and all the important information to the right service); moreover, the PSAP will be able to immediately inform the road/traffic management centres that an incident has occurred in a specific location and that the need to put diversions into operation has arisen there.

Fig. 1. Idea schematic of the e-Call system

Normative documents and draft standards related to the e-Call system [9.1, 9.3]:

1. **PN-EN ISO 24978:2010** – Intelligent transport systems – ITS Safety and emergency messages using any available wireless media – Data registry procedures;

2. **PN-EN 15722:2011** – Intelligent Transport Systems – eSafety – eCall minimum set of data (MSD);

3. **FprEN 16072** – Intelligent transport systems – eSafety – Pan-European eCall operating requirements;

4. **FprEN 16102:2011E** – Intelligent transport systems – eCall – Operating requirements for third party support;

5. **FprEN 16062:2011E** – Intelligent transport systems - ESafety - ECall high level application requirements (HLAP)

From the point of view of the logics of functioning of the e-Call system, the most important issue is the definition of the minimum set of data. This has been stipulated in standards, e.g. PN-EN 15722:2011 – *Intelligent Transport Systems – eSafety – eCall minimum set of data (MSD)* [3].

The minimum set of data comprises blocks of coded information, which include mandatory and optional fields denoted by M and O, respectively):

Block 1 (M) – ID (version of the MSD format);

Block 2 (M) – Message identifier (which counts the messages sent within the transmission, starting with 1);

Block 3 (M) – Control:

- Activation type (1 – automatic activation, 0 – manual activation);
- Call type (1 – test call, 0 – emergency call);
- Position reliability (1 – low, 0 – can be trusted);
- Vehicle type (category) encoding (0001 – M1, 0010 – M2, 0011 – M3, 0100 – N1, 0101 – N2, 0110 – N3, 0111 – L1e, 1000 – L2e, 1001 – L3e, 1010 – L4e, 1011 – L5e, 1100 – L6e, 1101 – L7e); for vehicle categories see framework Directive 2007/46/EC and for subcategories of the L category vehicles see Directive 2002/24/EC;

Block 4 (M) – Vehicle identification, with the VIN being specified there in accordance with standard ISO 3779;

Block 5 (M) – Vehicle propulsion storage (fuel) type, i.e. hydrogen, electric energy with more than 42 V and 100 Ah, LPG, CNG, diesel oil, or gasoline;

Block 6 (M) – Timestamp of the incident, in seconds elapsed from 1st January 1970;

Block 7 (M) – Vehicle location, with the latitude and longitude specified in accordance with standard ISO 6709;

Block 8 (M) – Vehicle direction of travel, specified as deviation from the north, with 2 deg accuracy;

Block 9 (O) – Most recent vehicle location (n-1) with respect to the current vehicle location specified in block 7;

Block 10 (O) – Previous vehicle location (n-2), immediately preceding the location specified in block 9;

Block 11 (O) – Number of passengers, based on the number of the safety belts having been fastened;

Block 12 (O) – Additional data.

It should be noted that additional information might be provided within the MSD package in the e-Call system. A concept of building information of this kind with the use of in-vehicle sensors and special encoders to define the type and category of the accident has been presented by the authors of this paper in publication [10].

3. Assessment of the collision effects having an impact on the vehicle passengers, based on data obtained from deceleration sensors

At a typical accident where a vehicle collision with an obstacle takes place, the e-Call system is activated or not depending on the estimated accident effects. These effects must be automatically assessed in the vehicle provided with deceleration sensors. A question obviously arises here, how the values of the deceleration sensor signals should be correlated with the biomedical indicators of accident severity.

To determine the correlation between the deceleration signals and the biomedical indicators, a number of impact tests and simulation calculations were carried out at the Automotive Industry Institute (PIMOT), the results of which were subsequently related to biomedical indicators.

Impact tests

The impact tests were related to a Suzuki Swift passenger car [6] hitting a solid obstacle. In result of the rig tests [9.2], not only the signals of deceleration measured at specific points of the car body and in the test dummy were recorded but also the coefficient of stiffness of the car body was determined (the value of the coefficient of stiffness is necessary for building a car model in the simulation program [5]). Then, the model was used for the carrying out of a number of crash simulations with impact speeds ranging from 80 km/h down to the speed level at which the passengers still might be injured. To assess the risk of bodily injury, the well-known Head Injury Criterion (HIC) was adopted as a parameter of assessment.

Head injuries are considered as being most dangerous among those likely to occur during an accident. The basic biomechanical parameter used for the estimation of possible head injuries is the deceleration acting on the human body during a collision. In most cases, head injuries result from head impacts against parts of vehicle interior or backrests of the seats ahead. The most severe cases are those with internal head injuries, which predominantly are extremely bad although invisible from the outside. The extensiveness and, in consequence, severity of the injuries depend on such factors as the impact strength and the age of the person injured. As an attempt to assess the head injuries in quantitative terms, a criterion based on the HIC indicator is used:

$$HIC = \max\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2} a(t)dt\right]^{2,5}(t_2 - t_1)$$

$a(t)$ – deceleration of the centre of mass of the head [g] (g – gravitational acceleration)

$(t_2 - t_1)$ – time of duration of the deceleration impulse [s]

Based on experiments, an assumption is made that if the numerical value of the HIC indicator exceeds 1 000 then a risk of fatal injury exists [4]. The research carried out by The Insurance Institute for Highway Safety in 2009 [8] has shown the value of HIC = 560 to be a limit above which severe injuries may occur.

In Federal Motor Vehicle Safety Standard (FMVSS) No. 208, the HIC indicator was modified by taking into account the duration of head acceleration impulse; in this connection, the limit values for HIC36 and HIC15 (the values of this criterion for an impulse duration time of 36 ms and 15 ms, respectively) were determined.

The crash tests as well as the recorded results of the tests and simulations have been shown in Figs. 2, 3, and 4.

Fig. 2. The Suzuki Swift car before and after the crash test; the impact speed was about 87 km/h

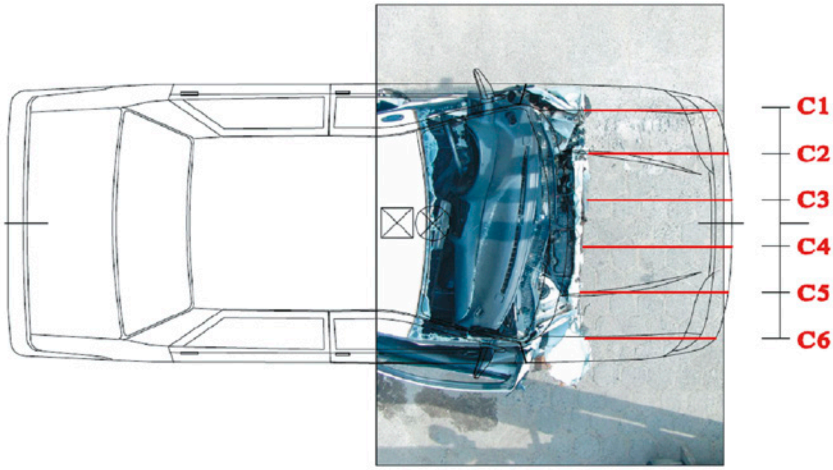


Fig. 3. The places where deformations of the front part of the Suzuki Swift car were measured

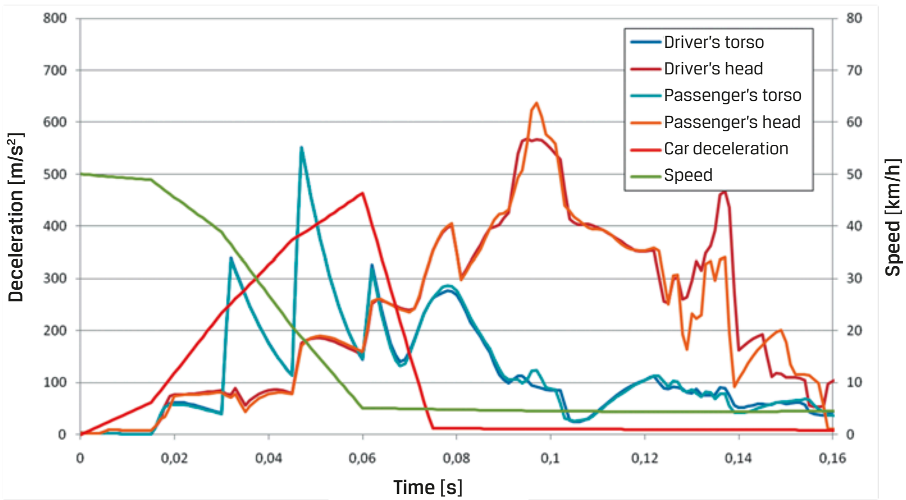


Fig. 4. Deceleration vs. time curves for the driver, passenger, and vehicle (computer model), for a speed of 50 km/h (typically adopted at type-approval tests), according to data obtained from sensors located as specified in the graph

Assessment of the injuries incurred in result of a road accident

The determining of the limit values for individual sensors was made dependent on results of calculations of the HIC indicator. The following values of the Head Injury Criterion were obtained from the simulation results:

For an impact speed of 87 km/h: HIC = 2100
60 km/h: HIC = 1225
50 km/h: HIC = 692
40 km/h: HIC = 379
30 km/h: HIC = 180
20 km/h: HIC = 40

To define the severity of the injuries incurred by passengers, the Abbreviated Injury Scale (AIS) was used.

The Abbreviated Injury Scale is the most popular method of descriptive evaluation of the severity of injuries incurred by the man as a motor vehicle user. The AIS system was first introduced in 1969 and it was several times revised and updated since then. It offers six severity classes, supplemented with two extreme cases that cover the situations with no injury and with injury of unknown severity.

Table 1. Injury severity classes according to the AIS system

AIS	Severity	Injuries (examples)	Fatality rate [%]
0	No injury		0.00
1	Minor	Abrasions, incised wounds, crushes, bruises, rib fracture, first and second degree burns of up to 10% of the total body area	0.00
2	Moderate	Abrasions and bruises of large body areas, extensive injuries to soft body parts, minor brain concussion with amnesia, second degree burns of up to 15% of the total body area	0.07
3	Serious, not life threatening	Skull bone fracture without liquorrhea, brain concussion with a loss of consciousness, pneumothorax, second degree burns of up to 25% of the total body area	2.91
4	Severe, life threatening, survival probable	Skull bone fracture with liquorrhea, brain concussion with a loss of consciousness for a period of up to 24 h, thorax perforation, second and third degree burns of up to 35% of the total body area	6.88
5	Critical, survival uncertain	Skull bone fracture with brain stem bleeding, body organ ruptured or torn off, third degree burns of up to 98% of the total body area	32.32

Table 1. Injury severity classes according to the AIS system cont.

AIS	Severity	Injuries (examples)	Fatality rate [%]
6	Maximal, currently untreatable	Severe head crush, brain stem laceration, basal skull fracture, thorax crush, aorta lacerated or cut, separation of thorax from pelvis	100.00
9	Unknown		nieznany

In most cases, the injuries incurred by vehicle passengers during a road accident cause the injured persons to be placed in hospital. Such injuries may be considered severe and, in AIS terms, they may be assigned a value of AIS ≥ 3.

The HIC values previously determined during crash simulations should be related to the scope of the injuries that may be incurred by the passengers. For this purpose, results of the research work done by *The Insurance Institute for Highway Safety* [8] were used, where *a value of HIC = 560 was adopted as the limit above which severe injuries may occur.*

This indicator should be correlated with the previously determined injury indicator value of AIS ≥ 3. The correlation will make it possible to determine the percentage probability of the occurrence of injuries with a severity degree of AIS ≥ 3 in relation to the HIC indicator value. With this end in view, an empirical formula was used, where the probability of the occurrence of injuries rated at AIS ≥ 3 was assumed as being dependent on the HIC indicator value [4]:

$$p(AIS \geq 3)_{HIC15} = \frac{1}{1 + e^{3,39 + \frac{200}{HIC_{15}} - 0,00372\,HIC_{15}}}$$

The above relationship is represented by a graph shown in Fig. 5.

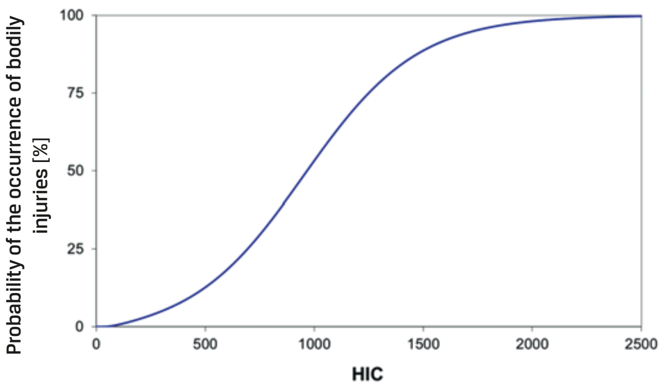


Fig. 5. Probability of the occurrence of bodily injuries with a severity degree of AIS ≥ 3

Based on the above formula, the probability of the occurrence of bodily injuries rated at AIS ≥ 3 was determined. For HIC = 560, it was found to be 15.9%.

The following conclusions may be drawn from the experiments, computer simulations, and calculations carried out at PIMOT:

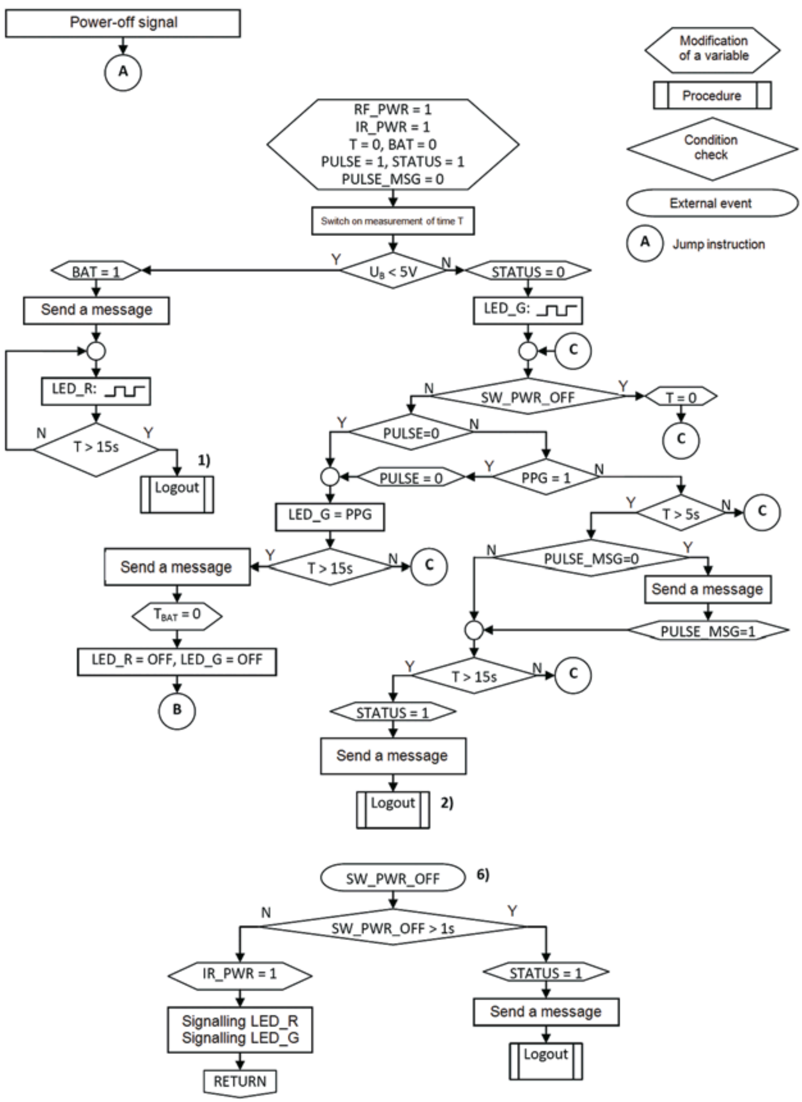
- The automatic accident notification system e-Call should be activated at decelerations starting from as low a value as that for which the Head Injury Criterion would be on a level of HIC = 560, i.e. a value for which a considerable risk (15.9%) of severe injuries (AIS ≥ 3) would be encountered;
- For the Suzuki Swift car tested at PIMOT at a frontal collision with a rigid obstacle (concrete wall), the HIC value of about 560 might be expected to occur at an impact speed within a range of 45 to 50 km/h (for 50 km/h, HIC = 692; for 40 km/h, HIC = 379);
- In real traffic conditions, i.e. in a situation where a vehicle travelling with a speed of 45 to 50 km/h hits frontally an obstacle other than the rigid one used at the tests (e.g. it hits asymmetrically a tree or another vehicle), the HIC value may be lower than 560; similarly, a different HIC value may occur if the coefficient of stiffness of the vehicle body differs from that determined for the Suzuki Swift car;
- At a time of about 0.06 s from the instant of impact against the rigid obstacle, the vehicle deceleration was about 470 m/s^2, i.e. about 50 g, at the crash test under consideration (V = 50 km/h, concrete wall).

4. Assessment of the collision effects having an impact on the vehicle passengers, based on data obtained from pulse sensors and cameras

The condition of participants in a collision may be assessed with the use of a special instrument set-up based on pulse sensors and cameras pointed towards the vehicle interior, with camera images taken frame-by-frame in about 15 s intervals from the impact.

According to the conceptual design of the system built for tests at PIMOT, the MSD block of additional data included coded information about the presence (or absence) of driver's pulse. This information is read and transmitted by radio from diode sensors installed in a bracelet on a driver's hand. The "frame-by-frame" pictures may be transmitted to the PSAP through a separate channel, apart from the MSD message transmission.

The pulse sensor system operates according to the following algorithm (Fig. 6):


Power-off signal
A
RF_PWR = 1
IR_PWR = 1
T = 0, BAT = 0
PULSE = 1, STATUS = 1
PULSE_MSG = 0
Switch on measurement of time T
U_B < 5V
BAT = 1
Send a message
LED_R:
T > 15s
Logout
1)
STATUS = 0
LED_G:
C
SW_PWR_OFF
T = 0
PULSE=0
PPG = 1
PULSE = 0
LED_G = PPG
T > 15s
Send a message
T_BAT = 0
LED_R = OFF, LED_G = OFF
B
T > 5s
PULSE_MSG=0
Send a message
PULSE_MSG=1
T > 15s
STATUS = 1
Send a message
Logout
2)
SW_PWR_OFF
6)
SW_PWR_OFF > 1s
IR_PWR = 1
Signalling LED_R
Signalling LED_G
RETURN
STATUS = 1
Send a message
Logout
Modification of a variable
Procedure
Condition check
External event
A
Jump instruction

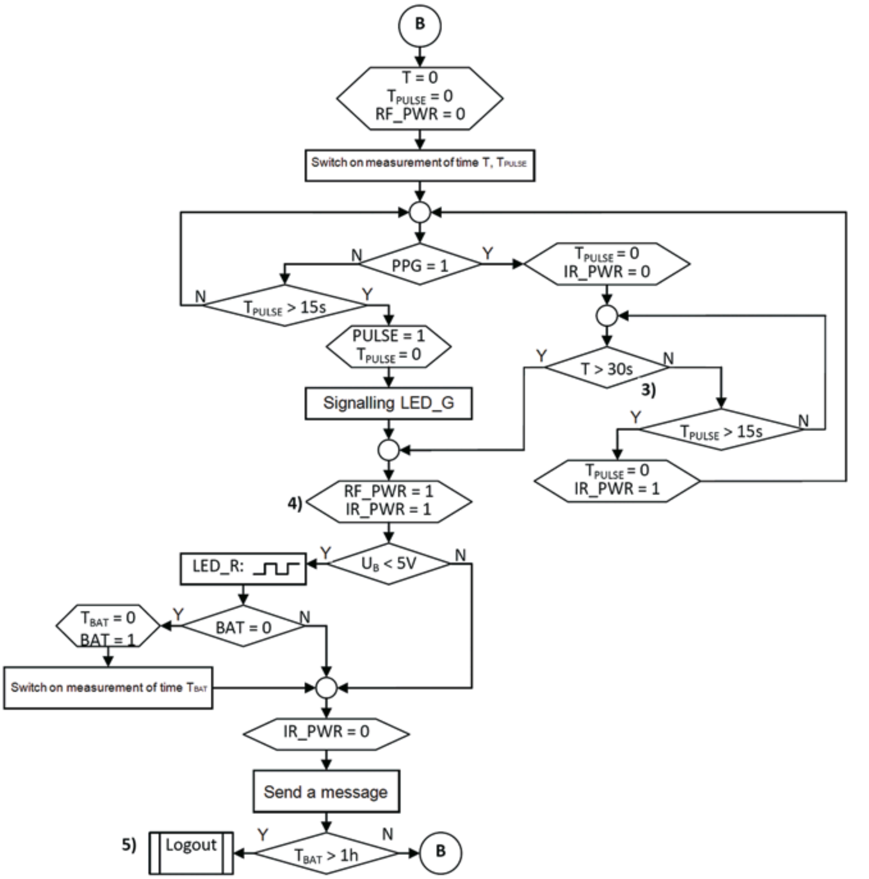


Fig. 6. Algorithm of operation of the pulse sensor [9.4]

Legend for the algorithm

Status signals:

Operation status (STATUS)	
0	Operation OK.
1	Logout (Power off)

Pulse status (PULSE)	
0	Pulse OK.
1	No pulse

Battery status (BAT)	
0	Battery OK.
1	$U_{BAT} < 5$ V

Controls:

Item	Symbol used in the algorithm	Function
1.	SW_PWR_ON	Power-on switch
2.	SW_PWR_OFF	Power-off switch or pulse readout and battery status check switch
3.	LED_R	Red LED: Signalling of the battery status
4.	LED_G	Green LED: Signalling of the pulse readout

Variables:

Symbol	Description
RF_PWR	Power supply to the radio transmitter module
IR_PWR	Power supply to the IR diode in the opto-isolator of the pulse reader
PPG	Pulse signal from the PPG module
T	The variable that controls the main time loop
T_{PULSE}	The variable that controls the pulse measurement time loop
T_{BAT}	The variable that controls the battery operation time loop
BAT	Battery status
U_B	Battery voltage
PULSE	Pulse status
STATUS	Operation status
PULSE_MSG	Information of a "No pulse" message having been sent

0 – OFF, closed, status "OK."
1 – ON, open, status "ERROR"

Description of the algorithm of the pulse sensor system:

1. When the power supply is switched on and the battery voltage is below 5 V, the reader will automatically turn off after an appropriate message is sent; if the battery voltage drops below 4.5 V, the reader will not switch on.
2. If no pulse signal is detected within 15 s from the power supply being switched ON, the reader will be automatically switched off after an appropriate message is sent out; the waiting time may be extended by depressing the SW_PWR_OFF button.
3. If correct pulse signal is received, messages are sent in 30 s intervals; if the pulse signal is not received, the message will be sent after 15 s.
4. The battery voltage is measured at full load (with the power supply to the IR diode and to the RF transmitter being on).
5. The reader will be active for 1 h from a battery voltage drop below 5 V; afterwards, the reader will be logged out from the system and switched off.
6. When the power-off switch is depressed for less than 1 s, the pulse and battery status signals will be displayed for 15 s; if the power-off switch is depressed for more than 1 s, the reader will be logged out from the system and its power supply will be switched off.

One of versions of the receiving unit (which receives signals from the pulse sensor) operates according to the following algorithm (Fig. 7):

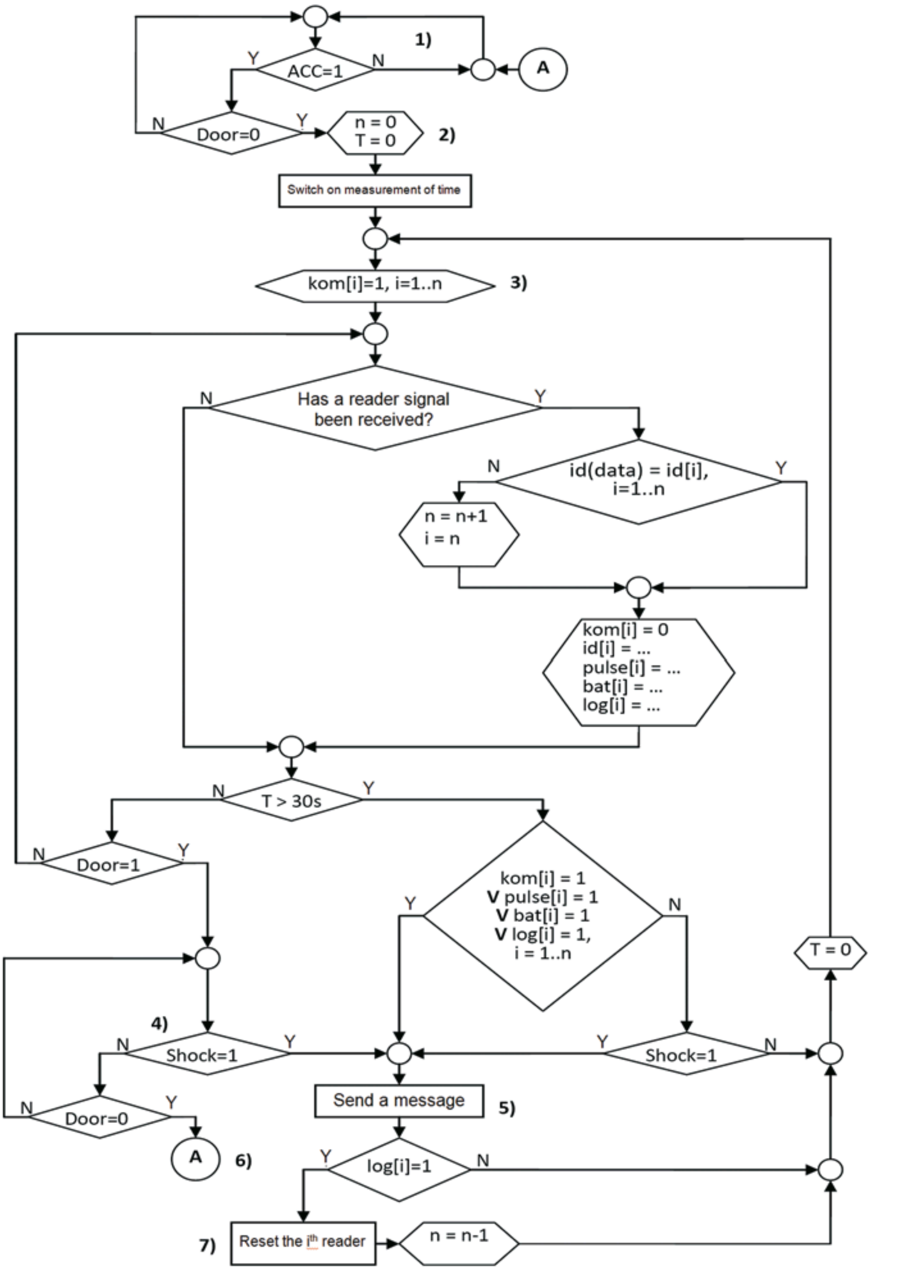


Fig. 7. Algorithm of operation of one of versions of the receiving unit that cooperates with the pulse sensor [9.4]

Legend for the algorithm

The symbols used in the algorithm should be understood as follows:

Variable	Description
n	Number of active readers
data	Message received from a reader
id[i]	Identifier of the ith reader
kom[i]	Status of communication with the ith reader
puls[i]	Status of the pulse signal received from the ith reader
bat[i]	Status of the battery of the ith reader
log[i]	Status of operation of the ith reader
ACC	Status of the ignition switch
Door	Status of the door sensors
Shock	Status of the collision sensor

0 – OFF, closed, status "OK."
1 – ON, open, status "ERROR"

Description of the algorithm of the receiving unit:

1. The vehicle is at a standstill.

2. Activation of the receiving unit.

3. The array, preliminarily filled with communication error signals, is successively zeroed as messages are received from individual readers; after a period of 30 s has passed, the fulfilment of a condition kom[i]=0 is checked for i=1..n (i.e. a check is run to see whether all the sensors have sent a message).

4. The door opening signal might result from damage to the sensor during the accident.

5. The message is only sent when one of the following events has occurred:
- The collision sensor has been actuated;
- No signal is transmitted from one or more sensors;
- No pulse signal has been received from one or more sensors;
- A battery in at least one sensor is running down;
- One or more sensors have been logged out.

Regardless of the reason for the message to be sent, the message includes data on the status of all the sensors and readers.

Within the message sending process, an acoustic signal is also generated to inform that a specific event has occurred.

6. After the door was closed, the number of vehicle passengers might have changed; therefore, the initial conditions must be checked again.

7. Logout of the sensor.

5. Final remarks

The e-Call system components must meet some technical requirements. Apart from the requirements essential for the functioning of the e-Call system, they must satisfy the standard requirements typically set down for electronic vehicle components and concerning installation functionality, power supply compatibility, electromagnetic compatibility, operational reliability, and immunity to interference of any kind (caused by e.g. short circuits in the system, power supply voltage drops, changes in ambient temperature, etc.). The requirements have been prepared at PIMOT in the form of relevant Technical Specifications [9.1].

References

[1] http://ec.europa.eu/health-eu/my_environment/road_safety/index_pl.htm (issue of 2013.09.12 – "Health-UE – road safety").

[2] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *eCall: Time for Deployment.* COM/2009/0434.

[3] PN-EN 15722:2011: *Intelligent Transport Systems – eSafety – eCall minimum set of data* (MSD).

[4] HADDADIN S., ALBU-SCHAFFER A., HIRZINGER G.: *Dummy Crash-Tests for the Evaluation of Rigid Human-Robot Impacts*. Institute of Robotics and Mechatronics DLR – German Aerospace Center.

[5] *Cyborg Idea V-SIM*, version 2.0.25, license No. 770AC72F issued for PIMOT – Automotive Industry Institute, Warszawa.

[6] http://www.autocentrum.pl/dane-techniczne/suzuki/swift/ii.html

[7] *Elektrotechnika i elektronika samochodowa, układy bezpieczeństwa i komfortu jazdy* (*Automotive Electrics, Automotive Electronics. Safety, Comfort and Convenience Systems*). Bosch Technical Instruction.

[8] Insurance Institute for Highway Safety: *Guidelines for Rating Injury Measures*, 1005 N. Glebe Road, Arlington, VA 22201, June 2009 - 2.

[9] PIMOT reports of the implementation of research project No. N N509 573239 "Development and testing of a car safety system within the structure of an 'intelligent vehicle'":

9.1. *Opracowanie założeń naukowo – technicznych dla systemu "inteligentnego pojazdu" (IP)* (*Preparation of scientific and engineering guidelines for an "intelligent vehicle" (IV) system*.

– Team Manager: Sławomir Łukjanow, D. Eng., associate professor.

9.2. *Identyfikacja parametrów oceny zdarzenia drogowego w odniesieniu do pojazdu* (*Identification of road incident assessment parameters*).

– Team Manager: Karol Zielonka, M. Eng.

9.3. *Analiza dokumentów prawnych w zakresie systemu samochodowych systemów bezpieczeństwa (SSB) i celowości wprowadzenia stosownych poprawek do prawa polskiego* (*Analysis of legal documents within the scope of the system of motor vehicle safety systems (MVSS) and of the advisability of introducing relevant amendments to the Polish law*).

– Team Manager: Magdalena Ambroziak, M. Sc.

9.4. *Analiza metrologiczna wybranych parametrów i funkcji do realizacji SSB* (*Metrological analysis of selected parameters and functions for the implementation of the MVSS concept*).

– Team Manager: Robert Berliński, M. Eng.

[10] ŻARDECKI D., PIJANOWSKI B.: *Informacja w samochodowym systemie bezpieczeństwa z funkcją „e-Call"* (*Information in the motor vehicle safety system with the "eCall" function*). The Archives of Automotive Engineering, 4/2012.