Abstract

This article presents a brief overview of the European automated emergency call (eCall) system and its main components and working principles. In details is described the In-vehicle system device (IVS) establishing the emergency call from the vehicle in case of an accident. It has been developed for testing the automated eCall integration in the Bulgarian emergency call system - 112. The article also contains diagram of the developed IVS internal software routines and graphics with example sensors data.

1. Introduction to eCall

ECall stands for „emergency call“ and it is initiative supported by the European Commission (EC). Its purpose is reducing road casualties by increasing the speed and efficiency of emergency response. Generally eCall involves a device installed in cars (IVS) that will manually or automatically connect a vehicle and its passengers to emergency services in case of an accident and will provide vital information such as vehicle location, time stamp, impact strength and etc. [1, 4, 5]

Figure 1 illustrates the basic concept and components of such eCall system. In case of an accident the incorporated IVS utilizes the emergency voice call to the local emergency agency (Public Safety Answering Point – PSAP) via the mobile network. These calls have special eCall flag indicating to the PSAP center that this is an automated emergency call which has to be routed to eCall responsible dispatchers. These dispatchers are supplied with special stations able to decode and visualize the received emergency data. Generally, the main purpose of the eCall flag is to distinguish regular emergency calls from the automated ones. It is set during the call set-up and has to be incorporated from the Mobile Network Operators.

The IVS also constantly monitors for vehicle location through one of the available Global Navigation Satellite Systems (GPS and/or GLONASS) or when it’s necessary through its internal sensors (if it has any). It is responsible for proper crash detection that can be done via external for the device car sensors (ex. vehicle airbags), through internal sensors (ex. accelerometer, gyroscope) or combination by both and etc.

The IVS provides two-way speech communication between the passengers and the emergency center operators. Emergency data transfer is realised through the GSM voice channel as technology like GPRS is not available on every location with mobile network coverage, also services like SMS has big time latency and etc. The data is encoded in Hybrid Automatic Repeat reQuest (H-ARQ) algorithm which is very suitable for transmission through all types of speech encoders used in mobile networks such as GSM full-rate and AMR encoders. Modulation of the GSM voice channel is implemented through eCall full-duplex in-band modem (eIM). It is suitable solution for such purposes as its incorporation in the existing GSM devices, is only a matter of firmware update. [1, 2]

ECall standardizes the transfer of a set of 140 data bytes, called Minimum Set of Data (MSD) sent from the vehicle to a Public Safety Answering Point (PSAP) [3]. This data includes MSD version, message identifier, automatic or manual eCall activation, VIN number, vehicle position, information about the vehicle propulsion system, time stamp and additional optional information.

MSD can be transmitted to the PSAP in two ways, pull and push modes. [2] In pull mode after an emergency voice call establishment, the IVS eIM receiver monitors the incoming signal, waiting for MSD request from the PSAP center. When the

Fig. 1. eCall system overview.
emergency data is requested, the IVS audio interface is muted and the eIM starts MSD transfer. After the data transfer is completed, the IVS un-mutes audio interface and the voice call between the IVS and the PSAP can continue. In push mode the data transfer is triggered by the IVS. It sends a request to the PSAP to pull the MSD data. After the data transmission, the IVS eIM enters idle mode and monitors new incoming messages from the PSAP's eIM. If it is necessary the IVS can transmit the MSD again.

2. Structure of In-vehicle system device

A simplified block diagram of the developed IVS is shown in figure 2. The main features of the IVS are implemented via dedicated embedded microcontroller unit (MCU) which processes the sensors data, gets the location information from the GNSS, controls the GSM module and utilizes the user and the communication interfaces. On the application layer the MCU implements crash detection, initiates the eCall and sends the MSD to the GSM module.

In order to fulfill the automotive industry requirements IVS has built-in CAN bus interface. It is used for information exchange between the vehicle’s electronic control unit and the IVS. The exchanged data can be VIN number, vehicle propulsion system and any additional information, which can be important and is available in the vehicle computer (GPS location, some vehicle status, airbags status, wheel position, brake activity, vehicle speed and etc.). As the CAN bus is only a physical level communication, for the different car brands and models a proprietary application level protocol is necessary.

The IVS is also equipped with trigger input in order to detect airbag sensor activation and give external crash event signaling. Additionally, it has two internal pulse inputs used for inputs from wheel position and odometer pulse outputs in case the vehicle has such available.

The device’s panel has mounted analog audio interface input/output 3.5 mm connector (see fig. 3). It can be used for establishing a connection to the car audio system or handsfree. For the need to conduct a voice call, an internal speaker and microphone interface are incorporated in the plug-in board.

The main purpose of the developed IVS is testing the incorporation of the eCall system in Bulgaria. Sufficient user interfaces are provided in order to achieve quick and easy work with the device. There are led outputs for different status indication like power supply, GSM network connection status and one led blinking in 1 pulse per second coming from the GPS receiver and indicating when it has fixed a position. Two inputs for push buttons are implemented for manual eCall and test eCall activation. Micro SD flash card is incorporated in the IVS used for storing all the sensors’ data along with the vehicle’s computer provided data necessary to facilitate the reason for accident, strength of the impact and etc. Such information is very useful for the crash investigation team, the insurance companies, the car manufacturers and etc. Because of the absence of a device display, a USB interface is used for PC connection. This interface suits best for the current application as the device has to be tested in vehicles and also all new mobile computers are provided with such interface. On the computer, the IVS appears as a virtual com port USB device and the necessary drivers are automatically installed by the computer’s operating system. So far tests were made with Window XP and 7. Controlling the device can be made through any terminal communication program such as Hyper Terminal, putty and etc. A special graphical application for the IVS has been developed. It enables easy and intuitive configuration and controlling of the device. The communication with the IVS is eased with an optional RS232 interface providing additional debug information.

The IVS incorporates several multipurpose sensors.

A 3-axis ±16g full-scale output digital accelerometer is used for crash detection. Crash event is signaled in case a deceleration above 2g applies to some of the monitored axis for time interval longer than 50 ms [6]. Frequency response of the sensor for the current implementation of the

Fig.2. Block diagram of an In-vehicle system device.
IVS is greater or equal to 100 Hz. These tree parameters are adjustable. Interface for high-g (above ±50g) inertial sensor is provided for impact logging. It can be mounted directly on the IVS body or on some external point, capable to provide accurate information of the impact. The data from the sensor can be used for vehicle body improvements and etc.

Magnetometer, gyroscope and barometer sensors can be used for inertial navigation (INS) in combination with the accelerometer. In case of GPS signal loss in tunnel or in city jungle, INS could give information about the vehicle’s position.

Temperature sensors are provided in order to monitor the internal temperature of the IVS. They can be used as fire detection alarm. Interface for external temperature sensor is available and can be used for ambient temperature. The external sensors placed on particular places can give accurate and reliable information but the communication with them can be cut out during the accident.

![Fig.3. In-vehicle system device.](image)

Important for the IVS is the tamper detection functionality. This function gives reliability of the recorded data as it detects whether the IVS case box has been opened and gives date and time of this event. It has battery back-up and is not interruptible on power loss. The tamper detect can be upgraded to signal to the responsible authorities on case box opening with an SMS for example.

Power supply of the IVS is based on high frequency DC/DC switching converter. It can work with input voltage from 8 to 26V. This provides the option to mount the IVS in trucks generally using 24V accumulator power supply system. The switching frequency of the DC/DC converter is selected at 1 MHz in order to avoid interference in the GSM voice channel. This is particularly important as the device transmits data over the speech channel. The probability of power cut during the vehicle accident is eliminated by using a Li-Ion backup battery power supply. It has to ensure minimum 15 operable minutes in voice call mode.

Figure 4 gives an overview of the most important IVS firmware functions and their hierarchical relations. On the Low Level Init are initialized the internal MCU peripherals. They include the general purpose inputs/outputs, all the necessary communication interfaces (USB, SDIO, USART, I2C, SPI) and peripheral modules like real time clock, timers and etc.

![Fig.4. Hierarchical firmware overview.](image)

On upper levels (second and third) are implemented all low level data exchange functions. These handlers transmit and receive data bytes which are used then by particular application routines. The application layer realized on these level handler functions includes specific sensors drivers, GSM/GPS AT command protocol, virtual com port functionality and file system maintained for the recorded data.

Additional interfaces such as I2C, SPI and USART are left intentionally on connectors in order to be used for communication with external sensors or various devices.

3. Results

The acceleration measuring results shown in figure 5 are obtained from the IVS’s inertial sensor.
They present a way for vehicle flip over detection, which event can trigger the eCall routine. The graphic shows 90 and 180 degrees tilts corresponding to 0g and -1g acceleration. The tilt of the vehicle is calculated with the following equation:

\[
\theta = \arctan \left( \frac{a_z}{\sqrt{a_x^2 + a_z^2}} \right)
\]

(1)

where \(a_x\) and \(a_z\) are acceleration over the X and Z measuring axis.

Tilt calculation with combination of two axes preserves the tilt versus acceleration sensitivity. The vehicle rotation in a plane parallel over the Earth surface is measured by the integrated magnetometer and gyroscope sensors.

![Fig.5. Acceleration on Z-axis.](image)

Figure 5. Acceleration on Z-axis.

Figure 6 shows plane rotation of the IVS using the data obtained from the magnetometer sensor. The difference of two adjacent data sets is used for detecting irregular vehicle rotations. For example difference larger than 50 mGauss means that the vehicle is turned over, which may trigger the eCall.

![Fig.6. Magnetometer output.](image)

Fig.6. Magnetometer output.

The incorporated gyroscope provides another method for detecting vehicle’s dangerous turn. Its output gives data directly in degrees per second which is more suitable for the purpose of the present application. ECcall can be triggered only by exceeding predefined maximum threshold of angular rate.

4. Conclusion

The developed IVS is successfully used in the Bulgarian pilot project for incorporation of the automated eCall system and in particular testing the PSAP center for proper respond and detection of the automated eCalls. Possible improvement of the IVS is expected to be its combination with GPS tracking system.

Bibliography (Style Chapter)


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