[1.]Alexandra Elisabeta LORINCZ, [2.]Simona CUCAILA

V2V / V2I COMMUNICATION SYSTEM FOR WARNING AUTO DRIVERS

[1.]University of Craiova, Faculty of Automation, Computers and Electronics, ROMANIA
[2.]University of Petrosani, Faculty of Mining, ROMANIA

Abstract: The use of vehicle communication can improve the safety, efficiency and productivity of a wide range of commercial vehicles. The use of wireless networks for vehicle communications and communications for other types of vehicles (freight wagons, buses, agricultural vehicles, construction vehicles and mining vehicles) can be achieved through the use of special devices implemented in these vehicles. These devices change information on road safety, mobility and the environment by informing the driver. Most of this information comes from sensors located on / in the vehicle. New technologies launched on the automotive market provide higher data read speeds and a much higher transfer rate. They can also quickly process new types of sensory data. An example is commercial vehicle sensors that process and interpret data from different types of sensors.
Keywords: communication systems, microcontrollers, transport protocols, vehicular ad hoc networks, vehicle safety

1. INTRODUCTION

The implementation of sensor systems and diagnostic systems to read the information provided by the ECU (electronic control unit) can lead to a smart complex system. Vehicle diagnosis is required to find defects or inappropriate operation. The communication made in the auto diagnosis has special devices as well as software dedicated to this. Custom protocols in this area contain information in the order of tens of bytes of data. The use of standards makes it possible to read all incoming bytes from the on-board computer of the vehicle [1], [2]. The need to use the devices specific to this automotive diagnostic area and the creation of software algorithms is very important. The hardware is flexible in choosing the modules that compose it, but the software part can be easily adapted to the requirements [3].

The software system is the most important part of the communication between vehicles and the communication between motor vehicles and road infrastructure. Presentation of how to create the algorithms used in data transmission as well as decrypting the data that are received from the modules used by the system [4]. Building the hardware is done with and around the STM32F100RB microcontroller using the development board. It sends, receives, encodes and decodes useful information until it is displayed on a graphical display. The realization of a system able to communicate with the vehicles around it, but also with the road infrastructure, is necessary for the possibility of its implementation on vehicles that do not have integrated intelligent systems [5].

The need for a correct choice of the "brain" of the system is based on the right balance between price, performance and energy consumption. Microcontroller (MCU) or microprocessor (MPU) becomes the basis of the main approach, based on the software development environment platform. The decision may have long-lasting consequences [6].

Below is the development of algorithms in the software environment, the creation and implementation of the communication protocol use. Choice of communication between modules and microcontroller by hardware implementation of electronic schemes [7].

2. DESIGN AND IMPLEMENTATION OF THE HARDWARE SYSTEM AND EQUIPMENT COMMUNICATION SOFTWARE

The system consists of two parts: the master part that is located in the vehicle with the K-line protocol as a diagnostic protocol and the Slave side that is located on the road infrastructure (road signs, traffic lights, barriers, pedestrian crossings, etc.). The Master device, which is used only inside the vehicle, performs several series of useful functions for communication around it [8], [9]. The tests were performed on EDC15P + Diesel ECU (038 906 019 KE) shown in Figure 1. Communication with the ECU was possible using the ISO 9141-2 protocol (K-line Slow) with the communication pins: pin 16 - K-line, GND and power supply (Figure 2).

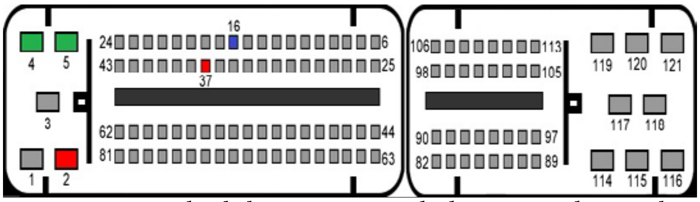

Figure 1. Wheel slip response with the proposed control algorithm

— **Presentation of ISO 9141-2 protocol characteristics (10.4 KB / sec)**

This protocol is used by Chrysler on European and Asian vehicles. The data transfer rate is up to 10.4 kb / sec. Data transmission is done on a single wire and the maximum voltage is 20 V. The 0 logic signal corresponds to the voltage range 0 - 3.5 V and the logic 1 corresponds to the 4.5 - 20 V voltage range (International Standard ISO 9141 -2, 1994). The length of the message is between 0 and 8 bytes [10, 11]. Connecting the STM32F100RB microcontroller with the ECU is done using an electronic circuit composed of resistors and a few transistors. The STM32F100RB uses the UART interface to send and receive information from the ECU using the UART_TX - PA9 and UART_RX - PA10 pins.

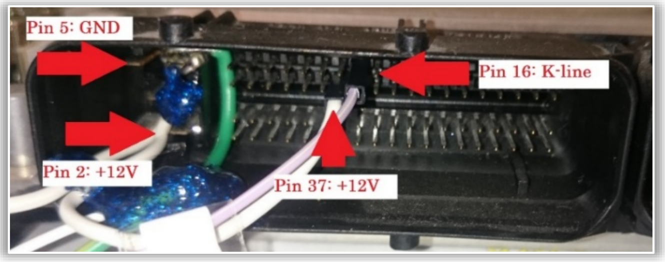

Figure 2. Making communication with ECU EDC15P +

Current consumption on the APART2 peripherals of the USART1 interface is 11.67 μA / MHz. The operating voltage of the microcontroller as well as the data transmission on the UART interface is 3.3V. The communication is done using BC546 transistors [12]. This is a bipolar NPN transistor that allows UCE collector-emitting voltages up to 60 Vdc and a UCB base collector up to 80 Vdc and a max IC collector current of up to 100 m Adc for power dissipation up to 625 mW at an ambient temperature of 25°C.

Each terminal designation specifies the function it performs, the collector: collects the electrical loads, the base: it can control the amount of load reaching the collector and the emitter: it is the main supplier of electrical loads. This whole circuit is used to convert the voltage logic levels in the +3.3V specific microcontroller range used in the + 12V range, since the k-line is a protocol that works at + 12V voltage.

Electronic scheme is developed and implemented in OrCAD Capture program, describing every detail and made electronic parts used. To create communication with an ECU, 5 resistors with 10kΩ values are required, two BC546 bipolar transistors and contact surfaces to provide the connections between the microcontroller and the microcontroller.

— **Algorithm of data generation and reading in equipment communications using ISO 9141**

We initialized communication with the electronic control unit ECU EDC15P + by transmitting the 0x33 address at a 5 baud rate, receiving the 0x55 response, changing the speed from 5 baud to 1400 baud, and the key words 0x08 [13]. The answer to the ECU is by transmitting the negative key word 2, and receiving the initially denied address, which signifies the successful completion of the initialization of the communication, see Table 1.

Table 1. Initialization of Electronic Control Unit Communication - ISO 9141-2 Standard

Time [s]	TX	RX	Description
-2.45E-02	0x33		Initialization of ISO 9141-2 communication - 5 baud address (Figure 3)
3.03E-01			
9.08E-01			
1.72E+00			
2.38E+00		0x55	Timing (Figure 4)
2.39E+00		0x08	Key Word 1 (Figure 4)
2.39E+00		0x08	Key Word 2 (Figure 4)
2.44E+00	0xF7		Key Word 2 denial (Figure 5)
2.47E+00		0xCC	Address denial 0x33 (Figure 6)

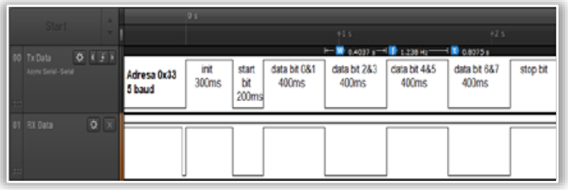

Figure 3. Initiate ECU communication via Slow Init (5 baud) of ISO 9141-2 protocol

Figure 4. Answer received from the ECU with the sync byte, KW1 and KW2 (10400 baud)

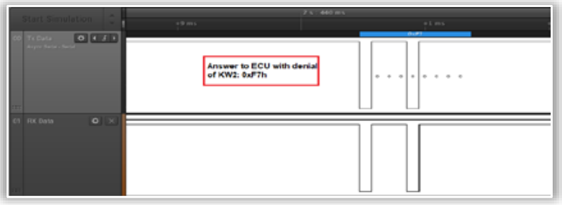

Figure 5. The response sent to the ECU with the denied KW2 byte (10400 baud)

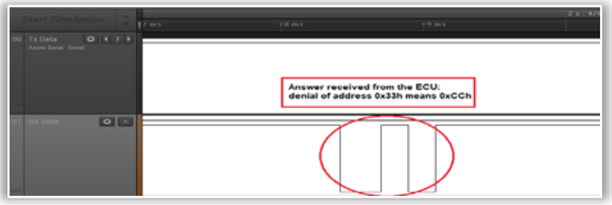

Figure 6. Receiving the negated 0x33 address from the ECU, that is, the byte 0xCC (10400 baud). Acceptance of ECU communication

Composing messages is done using protocol-specific MODs and PIDs. Successive sending is required for real-time display of values read from the ECU, see Table 2.

The query is executed in 5 specific messages. After each submission, a specific response time is expected which, by special algorithms created using the ISO 9141 standard, decrypts data and displays them on the graphical display. Commands for reading information such as speed, rotation per minute, or if the engine control indicator is lit are defined in the send_message function that includes the calculation for the checksum byte used to verify the correctness. This byte is added at the end of the data string [14]. The software is tested on an EDC15P + Diesel ECU. After the MOD 01 PID 21 is interrogated, the received data are presented (Figures 7 and 8):

Table 2. Example of Write and Read Data for Engine Rotation Per Minute

Time [s]	TX	RX	Description
3.44E+00	0x68		Header 1
3.45E+00	0x6A		Header 2
3.46E+00	0xF1		ECU address
3.46E+00	0x01		MOD 01
3.47E+00	0x0C		PID 0x0C
3.48E+00	0xD0		CheckSum 8 bits
3.51E+00		0x48	Header 1
3.52E+00		0x6B	Header 2
3.52E+00		0x00	ECU address
3.52E+00		0x41	MOD 01
3.52E+00		0x0C	PID 0x0C
3.52E+00		0x00	Answer (A)
3.53E+00		0x00	Answer (B)
3.53E+00		0x00	CS

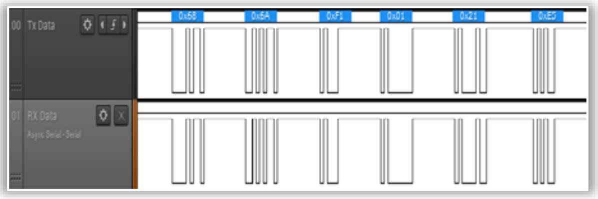

Figure 7. Data transmitted to the ECU and verified with the SALEAE Logic Analyzer (0x68 0x6A 0xF1 0x01 0x21 0xE5)

Figure 8. Data received from the ECU and verified with the SALEAE Logic analyzer (0x48 0x6B 0x00 0x41 0x21 0x00 0x00 0x15)

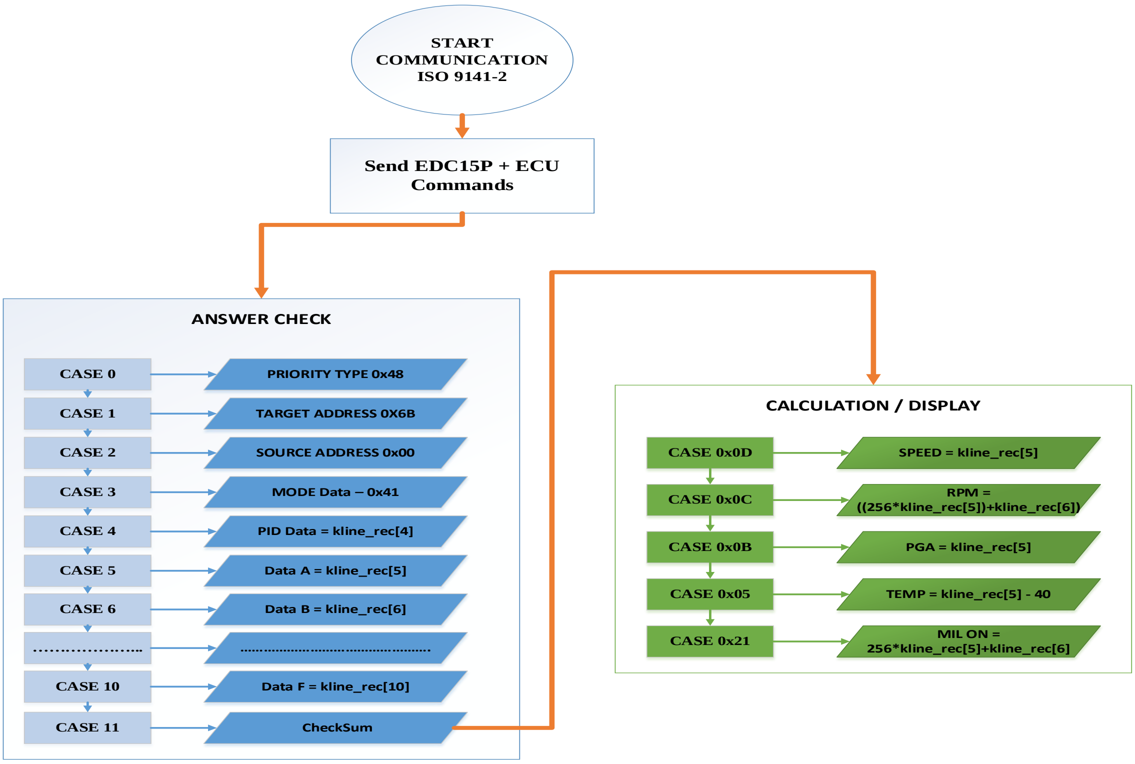

Figure 9. Making communication with ECU EDC15P +

For each composite message, add the byte for verifying the message's correctness, bytes checksum. The calculation for this byte is executed in its specific function using Modulo 256.

3. DEVELOPMENT OF THE V2V / V2I SYSTEM USING CORTEX M3 AND OPTICAL SENSORS

To build the V2V / V2I system, we used the optical sensors that are located to the right and left of the vehicle. These sensors are set to sense objects around the vehicle at a distance of no more than 80 cm with a sensitivity range of 15°. They announce the driver if there are objects or vehicles on the sides of the vehicle (Figure 10) [15], [16]. The signals received from the E18-D80NK sensors are digital signals read by the STM32F100RB microcontroller on port C and pins 2 and 3. Sensor data is displayed on the vehicle's LCD.

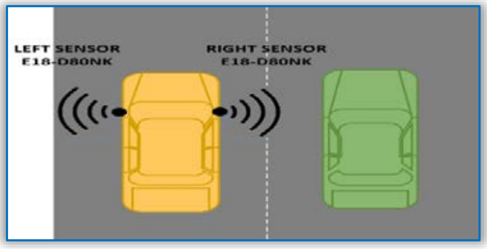

Figure 10. Making communication with ECU EDC15P +

Figure 11. E18-D80NK left / right sensors located on the V2V / V2I test bench

We analyzed traffic lanes with a standard width of 2.75 meters and a maximum of 3 meters. For this reason, the sensors used in the vehicle's sides fit for reading the surrounding objects, but also the vehicles that can run in parallel with it [17]. Figure 11 shows the E18-D80NK sensors that we used for the V2V / V2I test and prototyping stand.

From the analysis of the parameters and characteristics of the sensors we used and we considered the LV-MAXSONAR-EZ sensor to be located on the front bar of the vehicle because it has a measuring distance of up to 6.45 meters. From this analysis we deduced the driver's response time when the vehicle in front of him suddenly brakes. If the sensor had a smaller reading distance, then the driver's response time decreased significantly. The LV-MAXSONAR is connected to STM32F100RB on port C on pin 0. It reads the analog signals transmitted by the sensor with the resolution of 10 bits and displays on the LCD if there are objects or vehicles in front of it (Figure 12).

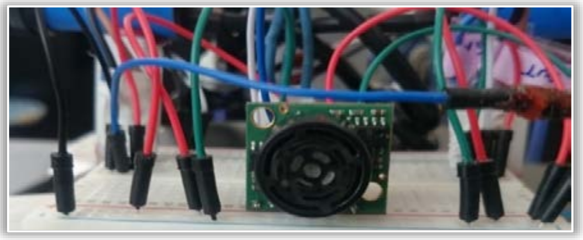

Figure 12. The LV-MAXSONAR sensor located on the V2V / V2I system test stand

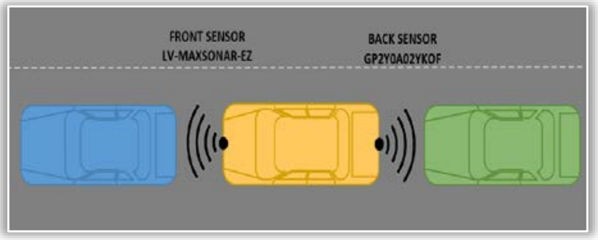

Figure 13. Location of the LV-MAXSONAR and GP2Y0A02YKOF sensors on the vehicle

Using the data from the vehicles around, knowing the speed and the readings from the LV-MAXSONAR sensor, the algorithm we created warns the driver of the major traffic changes. For example, if the vehicle moves ahead of another vehicle at a speed of 80km / h, and at a certain point it suddenly brakes, the microcontroller warns the driver of the changes that occurred [18]. The algorithm has composed it to consider only the major changes that occurred, not to load the network with messages from the surrounding vehicles, these messages having specific priorities [19]. An example of a traffic situation is shown in Figure 13.

The GP2Y0A02YKOF sensor was used to verify that there is an object or other vehicle behind the vehicle when it is in motion or when it is stationary. This sensor communicates with the STM32F100RB microcontroller and is connected to port C on pin 1. The data transmitted to the STM32F100RB are analog data with an 8-bit resolution. The measuring distance is 1.50 meters with a radius of 40 ° sensitivity.

The road code does not specify a specific distance to be kept in traffic [20]. It is assumed that a sufficient distance should be maintained to avoid collision, in which case the chosen sensor makes it possible to find out the distance from the vehicle behind. Most times, we meet drivers who stop very close to the vehicle in front of them. In these situations, it can prevent or even avoid road accidents, knowing the dangers behind and acting preventively against these drivers driving the distance between cars. Data received from the sensor is displayed on the LCD included in the V22 / V2I system.

The location of "SLAVE" devices on road signs helps to transmit the data about their category and the driver's early warning. These "SLAVE" devices have in their structure the RFM12B radio module that allows communication within a radius of about 100 meters in open space.

In certain meteorological conditions, but not only, we considered it to be beneficial to identify road signs in time, especially when they are going through an unknown road.

We present the "SLAVE" part of the V2V / V2I system, where we designed two "SLAVE" devices that are specific to the road banner categories (known as 0x02) and bindings (0x03) (Table 3). For the prohibition category we chose the INTERVENTION STANDARD road marker and for the bridging category we chose the FORWARD OBLIGATORY GUIDE. They act as transmitters to convey their specific messages to traffic participants. The messages received by the "participants", which are actually the vehicles within the marker range, receive and display the sign of the indicators on the vehicle's LCD.

Table 3. Structure of the transmitted / received message

Sequence	Description	Hexadecimal
Byte 1 and Byte 2	The first byte header for message	0xAA and 0xAA
Byte 3	The second byte header for the message	0x2D
Byte 4	The third byte header for the message	0xD4
Byte 5	Length of message	0x0E
Byte 6 to Byte 13	Data bytes (to 8 bytes)	0xXX
Byte 14	Stop byte	0xAA
Byte 15	CRC – 8 bits	0xYY

Data bits have priorities based on cars, road signs, traffic lights. The first data byte has the highest priority information, indicating the reception of the message from a motor vehicle, road indicator or traffic light. The rest of the bytes hold data according to the category they belong to. Table 4 describes the data transmitted or received by vehicles using the V2V / V2I system.
For traffic lights using the V2V / V2I system, the structure of the message is different from that of the vehicles. This message transmits the traffic light and every second it resubmits, announcing the number of minutes and seconds left (Table 4).

Table 4. Specify transmitted / received data in the V2V / V2I system

Data Bytes	Traffic lights messages	Decimal	Traffic sign messages	Decimal	Vehicle messages	Decimal
Byte 0	0x02		0x01		0x00	
Byte 1	Red: 0xFF Yellow: 0x55 Green: 0x11		IndR1: - Category of road signs: 0x00 - 0x07	0 - 7	Speed: 0x00 - 0xFF	0 - 255
Byte 2	Minutes left: 0x00 - 0x0A	0 - 10 min	Traffic sign: 0x00 - 0xtt		RPM1: 0x00 - 0x3FFF	0 - 16383.75
Byte 3	Seconds left: 0x00 - 0x3C	0 - 60 sec	IndR1: - Category of road signs: 0x00 - 0x07	0 - 7	RPM2: 0x00 - 0x3FFF	
Byte 4	0x00		Traffic sign: 0x00 - 0xtt		Temp: 0x00 - 0xFF	-40 - 215
Byte 5	0x00		IndR1: - Category of road signs: 0x00 - 0x07	0 - 7	PGA: 0x00 - 0xFF	0 - 255
Byte 6	0x00		Traffic sign: 0x00 - 0xtt		MIL1: 0x00 - 0xFFFF	0 - 65535
Byte 7	0x00		0x00		MIL2: 0x00 - 0xFFF	

Road signs are met alone or more in one place. For this reason, the message compresses all road data. These may be different, which results, dividing them into 8 specific categories. The display of 3 indicators in a different category or category is the maximum that the space reserved for this purpose on the LCD screen can support (Table 4 and 5).

Table 5. Category of road signs in V2V / V2I system

Value (hex)	Category of road signs	Traffic sign
0x00	Warning Circulation Signs	0x01 - 0x38
0x01	Signs of priority traffic	0x39 - 0x3E
0x02	Traffic signs of ban and restriction	0x3F - 0x66
0x03	Circulation signs of obligation	0x67 - 0x72
0x04	Traffic direction signs	0x73 - 0x95
0x05	Signs of information circulation	0x96 - 0xC5
0x06	Signs of tourist information circulation	0xC6 - 0xD1
0x07	Additional panels	0xD2 - 0xE8

The "MASTER" part of the V2V / V2I system, which consists of the K-line module that makes it possible to communicate with the ECU EDC15P + using the ISO 9141-2 protocol, the "brain" of the system is the STM32VLDISCOVERY development board containing the microcontroller STM32F100RB. Construction of the printed circuit was possible using the OrCAD development environment. The connection of the three pins (+ 12V, GND and K-line) to the development board, respectively the STM32F100RB microcontroller, makes synchronous communication possible for real-time data exchange with the ECU.
We have built this "MASTER" device that makes it possible to communicate with surrounding vehicles and road infrastructure by using radio signals. All this information is decrypted and identified on the graphical LCD where it can be viewed by the driver or owner of the car. Communication with the radio module is through the SPI interface and the module-specific commands are used.
We made connections to the graphical display NHD-C12864LZ-FSW-FBW-3V3, its communication being based on the ST7565R controller, and the communication is a type 8080 (parallel communication). Data read from the onboard computer, from the front / rear and left / right sensors and the data received via the RFM12B radio modules are displayed.

Due to the use of the on-board computer without the necessary connections, it does not receive information from the devices in the vehicle construction, other computers or sensors, for this reason the received and displayed values are equal to 0 or erroneous (e.g. temperature).

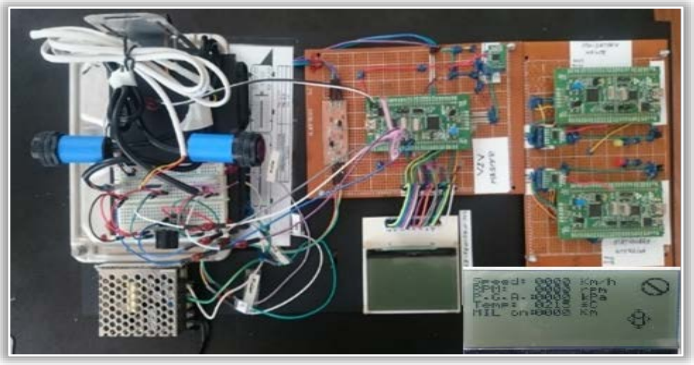

Figure 14. The stand of the V2V / V2I system. ECU reading, traffic sign and distance sensors

4. CONCLUSION

In this paper is presented how to read the data from the ECU using the diagnostic protocol ISO 9141 and the information is displayed on a graphical LCD (vehicle speed, RPM, engine temperature, distance traveled with activated MIL). All of this data is transmitted to the surrounding vehicles using the RFM12B radio module that has FSK digital modulation. The data received from the road signs are also displayed on the graphical LCD. Presentation of the program writing mode for the STM32F100RB microcontroller and its programming for the optimal operation of the V2V / V2I system. Creating and presenting the V2V / V2I communication protocol with the algorithms needed to encrypt and decrypt the information.

Presenting communication between remote sensors and the STM32F100RB microcontroller that informs the driver of the dangers surrounding it to help avoid unintended traffic situations.

The functionality of the system has been tested on the stand made of ECU, development boards with cortex m3 microcontrollers (STM32F100RB), RFM12B radio modules, distance sensors and graphical LCD. This data helps to implement the system on vehicles that do not have intelligent driver warning systems.

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