Design and implementation of a prototype vehicle location and security system with GPS and GSM communication, based on hardware and free software

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***Abstract*—This work presents the design and implementation process of a highly technological and small size device, based on vehicle location and control of various vehicle parameters. The proposed prototype is composed of six blocks between the taking part of the decisions to be executed by a relay system to the devices to be controlled in the vehicle, passing also by the acquisition of the GPS signals of the satellites in Orbit, also the communication system for sending and receiving phone calls and SMS through the Android application, finally, the power supply and backup system. The implementation process and functional tests show the applicability of the prototype thus obtaining a high technology system and small size.**

***Index Terms*—Vehicle safety; Open-source; Global Positioning System; Global System for Mobile communications; Near Field Communication; Android; Arduino.**

I. INTRODUCTION

High delinquency rate in Ecuador today, coupled with the high cost of existing security systems, mean that vehicle owners do not opt for smart devices to protect them, making them easy targets for criminals, It is worth noting that according to the latest study carried out by CEDATOS in 2011, which shows an increase in crime in Ecuador and indicates that 65% of the population has been victimized or has a family member who has been victim of a crime Criminal [1].

On the other hand, vehicle owners only prefer to opt for economical common alarm systems, which provide a minimum degree of safety and also do not offer control of the vehicle, which is not enough for a country with a high degree of delinquency and theft of vehicles, which is why we have opted for the design of a prototype vehicle location and security system with the purpose of eradicating vehicle theft and express abductions, if in some unexpected situation a mishap occurred and we wanted know the exact location of the vehicle or otherwise have a control of the ignition or the insurance of the doors, the system must allow to know and control various parameters of the vehicle remotely, for it uses modern technologies such as GPS, GSM and NFC, in order to obtain a highly technological system and with the benefit of being economical compared to other similar systems.

II. DESIGN OF PROTOTYPE

The best way to eradicate the large amount of vehicle theft and loss of life caused by express abductions is by helping to inform the vehicle user of an unexpected situation where timely care is required, thus avoiding any human tragedy or material, all this by means of alerts and telephone calls to an emergency number. On the other hand, to prevent the offender from stealing the vehicle, it is essential to incorporate an ignition control system, thus blocking the engine starting functions; Finally, to help inform the exact location of the vehicle within the Ecuadorian territory, it is essential to place a modern vehicular localization system.

As mentioned before, it has been proposed to develop a prototype that allows the location of the vehicle based on the implementation of a GPS module on board the vehicle, also the prototype will allow the authorization of ignition of the vehicle based on the reading of MIFARE tags through an NFC reader, on the other hand, will implement a panic button that allows sending an SMS to an emergency number, reporting an emergency situation, then make a phone call allowing the emergency smartphone to listen to the conversation that takes place in the Interior of the vehicle, with the possibility of recording the audio automatically; finally, an Android application will be designed to allow the control of all the features offered by the prototype, with the possibility of registering the owner of the vehicle to the prototype based on the cell number, this is done to prevent others from doing use of the application and in this way commit some criminal fact.

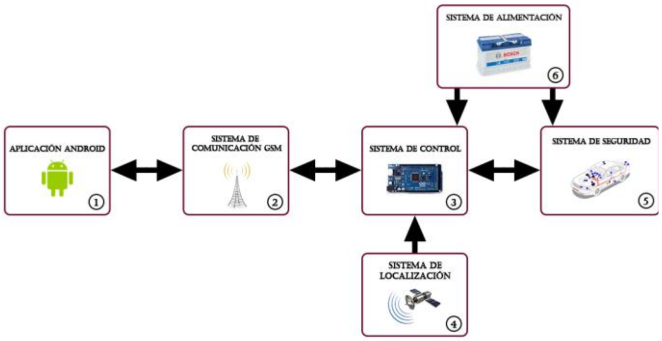

Fig. 1. General block diagram of the Vehicle Location and Safety System prototype.

Figure 1 shows the general block diagram of the prototype, which is made up of the Control System block, which is in charge of governing the entire prototype and where all the communication modules are interconnected, as well is made up of the Security System block, which is responsible for complying with the actions that are determined in the Control System, this block also interacts directly with the vehicle's own devices, such as the gas pump and the central lock of doors; on the other hand there is the GSM Communication System block, which allows the transport of requests and responses generated both by the Android application as well as by the Control System; There is also the Location System block that is responsible for capturing the GPS signals sent by satellites in orbit, and then send them to the Control System, processing them and converting them to a predefined format; Finally, the block of Power System that is responsible for supplying the necessary voltage to each of the devices and modules that make up the prototype.

A. Control System

The main element of the Control System is the electronic development board Arduino Mega 2560, which consists of all the pins and communication protocols necessary for the interconnection of each of the devices that make up the entire prototype.

Fig. 2. Arduino Mega 2560.

TABLE I
Technical specifications Arduino Mega 2560

Characteristic	Detail
Microcontroller	ATmega2560
Operating Voltage	5V
Input voltage (recommended)	7-12V
E/S Digital Pin	54 (15 PWM out)
Analog input pins	16
DC current for E/S pin	20 mA
DC current for 3,3V pin	50 mA
Flash memory	256 KB, 8 KB used by the bootloader
SRAM	8 KB
EEPROM	4 KB
Clock	16 MHz
Length	101.52 mm
Width	53.3 mm

Table I allows to observe the technical specifications of the electronic board Arduino Mega 2560 [2], where the following is the characteristics used for the development of the prototype:

- It has four UART ports that serve as communication protocol for GPS and GSM modules.
- It provides 54 digital I / O, which allows to connect the different devices, such as the panic button, relay connection outputs for the gasoline pump, electric locks, among others; Providing scalability to adapt more devices if necessary without any problems.
- It has SPI communication, which allows the connection of the NFC module that is one that allows reading the MIFARE tags that authorize the ignition of the vehicle.
- It incorporates EEPROM memory, which is essential in the development of this project, since in this memory important data of the state of the vehicle are kept.

B. Security System

The Security System has as objective the fulfillment of the actions that in the Control System are determined, these actions are the following:

- Carry out the readings through the NFC reader module of the MIFARE identification cards or key chains delivered to the user of the vehicle.
- Always feel the panic button, this will be operated by the user of the vehicle when there is an emergency situation.
- Carry out actions of locking or unlocking the petrol pump, to authorize or not to activate the vehicle.
- Activate or deactivate the electric door locks.
- Issue on the base of the buzzer the informational sounds of the state of the vehicle.
- Carry out control of the vehicle contact system, to be later controlled by the prototype Control System.

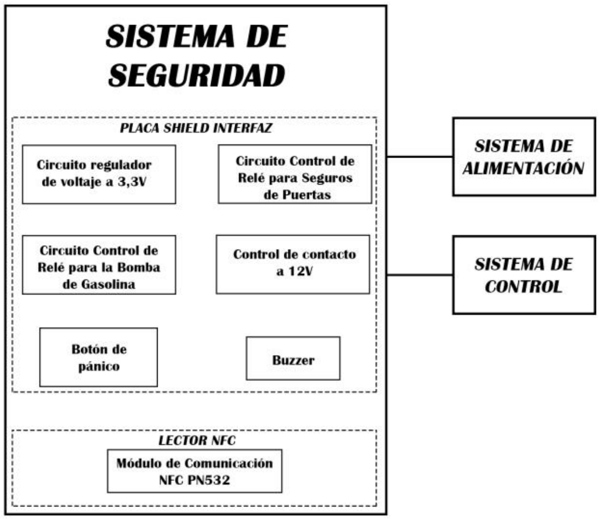

Fig. 3. Block diagram of the Security System.

Figure 3 shows how the Security System is formed, it should be emphasized that it consists of two large sets, which are the Shield Interface board and the NFC Reader; in which each set consists of several blocks which are designed separately to form the entire system.

On the one hand, there is the NFC module which is responsible for reading the MIFARE ID cards or key chains delivered to the user, and then authorize or not the vehicle ignition.

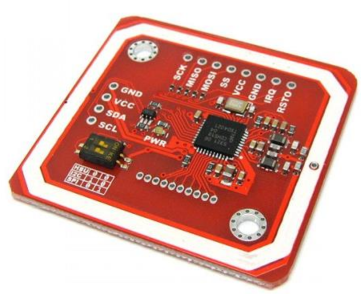

Fig. 4. NFC PN532 module.

Figure 4 shows the physical form of the NFC module PN532, which consists of a DIP switch selector of the communication protocol to be used, for this project will be made use of the SPI protocol, which is made up of the MOSI, MISO, SCK and SS [3].

TABLE II
Technical specifications NFC PN532 module

Characteristic	Detail
Communication	I2C, SPI y HSU (High Speed UART)
Supply voltage	3,3v – SPI 5V – I2C y UART
RFID modes	Reading/writing Mifare 1k, 4k, Ultralight, y DesFire
Antenna	PCB incorporated, 5-7cm of communication distance
Power Consumption	Standby: 100mA Reading/writing: 120mA
Size	43mm*41mm*4mm

Table II allows to observe the specifications of the communication module NFC PN532, where it is possible to emphasize that it has a small size, easy integration thanks to the protocols I2C, SPI and HSU that provides, on the other hand, it allows the reading and writing of tags with MIFARE technology, an important feature given that thanks to this it is possible to encrypt the tags with security keys that prevent the cloning of them.

On the other hand, is the Shield Interface board, which is one of the most important stages in the development of this project, because it is in charge of allowing the communication of the different modules that make up the prototype, which in this case are the panic button, gasoline pump, central door lock module of the vehicle, vehicle contact signal, buzzer, and NFC module power.

One of the blocks that make up the Shield Interface board is the 3.3V voltage regulator circuit, which is responsible for providing the necessary voltage and current to the GPS and NFC modules.

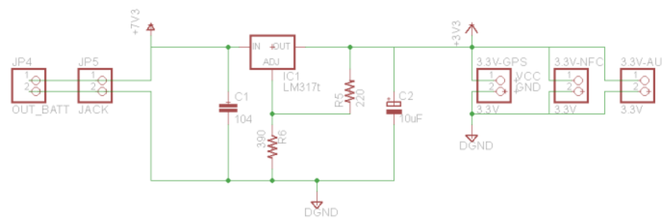

Fig. 5. Electrical diagram of the 3.3V voltage regulator circuit.

Figure 5 shows the electrical diagram that is mainly formed by the integrated circuit LM317t [4] which, by calculating two resistors, it is possible to obtain a fixed output voltage, which in this case will be 3.3v, having as 12V input voltage obtained directly from the vehicle's main battery.

To calculate the resistances, R1 = 220Ω, Vout = 3.3V was used as the input data, then replacing this data in equation 1 can obtain the value R2.

$$R2 = \left(\frac{R1}{1{,}25}\right)(Vout - 1{,}25) \quad (1)$$

After replacing data, the value of R2 = 360.8Ω is finally obtained for design purposes, but for commercial purposes the value of 390Ω will be used. In addition, it is necessary to calculate the power value dissipated by each of the resistors, then proceed to make the corresponding similar calculation for R1 and R2, using equation 2:

$$P(R1) = \frac{(V_{R1})^2}{R1} \quad (2)$$

Finally, we have for R1 = 7mW and for R2 = 11.67mW, concluding that the resistance and power values to be used are for R1 = 220Ω to 1 / 4W, and for R2 = 390Ω to 1 / 4W.

Another block that forms the shield Shield Interface is the relay control circuit for the door locks, which allows the activation of the relay that will allow the conduction of a ground signal, this will allow the action of opening or closing doors according to the case, since two similar circuits are required.

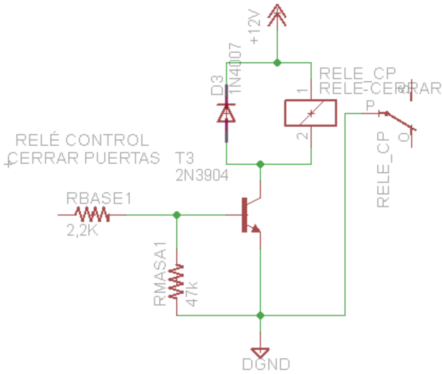

Fig. 6. Relay control circuit for vehicle door locks.

To achieve this, it is necessary to use a transistor to amplify the current provided by the Arduino Mega 2560 digital pins, which are 20mA, which is not sufficient since a common relay can be activated normally with a current of between 50mA and 150mA measured in a practical way. In addition, it is also necessary to perform the calculation of the basic resistance, which is calculated with equation 3.

$$Rb = \frac{(Vcc - Vbe) * Hfe}{Ic} \quad (3)$$

Taking values Vcc = 5V, Vbe = 0.7V, Hfe = 30 and Ic = 70mA and replacing the values in the equation, we finally have the value of Rb = 1842Ω for design purposes, but for commercial purposes it is used The value of 2.2kΩ. It is also necessary to use a mass resistance, which is recommended to be of a value large enough to not alter the calculation of the base resistance, then the value of Rmasa = 47kΩ. Finally, as previously done, it is necessary to calculate the power value dissipated by each of the resistors, for this use is made of equation 4, which serves both Rb and Rmasa.

$$P(Rb) = \frac{(V_{Rb})^2}{Rb} \quad (4)$$

The value of the voltage for the base resistor is $V_{Rb} = V_{cc} - V_{be} = 5V - 0{,}7V = 4{,}3V$, and for the ground resistance is $V_{Rb} = V_{be} = 0{,}7V$, now replacing these values in equation 4, $P(Rb) = 10{,}03mW$ and $P(Rmasa) = 10{,}425\mu W$; Finally concluding that the resistance and power values to be used are, for Rb = 2.2kΩ to 1 / 4W, and for Rmasa = 47kΩ to 1 / 4W.

A block similar to the one above, is the one that allows controlling the relay that will trigger the operation of the gasoline pump, in the event that the vehicle ignition is authorized, the relay control circuit is shown in figure 7, this to unlike the previous one, it allows the activation of automotive relays, as it is in this case, since for the actuation of the same it is necessary a current of around 135mA measured in a practical way.

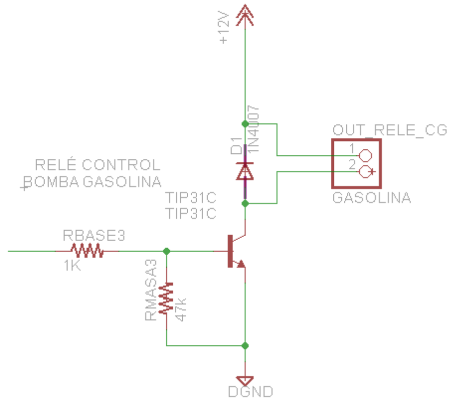

Fig. 7. Relay control circuit using an NPN transistor TIP31C.

In order to achieve such a drive current, it is necessary to use an amplifier transistor, in this case it is the TIP31C, since it provides a maximum collector current of up to 3A [5], now similar to the previous circuit, it is necessary to calculate the resistance of both base and mass, to speed up the calculations it is necessary to mention that equations 3 and 4 above were used; Where we have as data that Vcc = 5V, Vbe = 0.7V, Hfe = 25 and Ic = 135mA, after replacing the data in equation 3 we have that Rb = 769,29Ω for design purposes, but for purposes Commercial is used the value of Rb = 1kΩ, now the resistance of mass is maintained in the same way with a value of Rmasa = 47kΩ. To conclude this block it is necessary to calculate the power dissipated by each of the resistors, then for the two resistors use is made of equation 4, now for the base resistance $V_{Rb} = V_{cc} - V_{be} = 5V - 0{,}7V = 4{,}3V$ and for the mass resistance $V_{Rb} = V_{be} = 0{,}7V$, replacing these data in equation 4 for each case, finally the dissipated power is obtained, where $P(Rb) = 24mW$ and $P(Rmasa) = 10{,}425\mu W$; Finally concluding that the resistance and power values to be used are, Rb = 1kΩ at 1 / 4W, and Rmasa = 47kΩ at 1 / 4W.

A block designed also is the Contact Control at 12V, this allows to make use of the vehicle's own contact signal, allowing the prototype in this way to verify that the key was placed and put into contact status, then through the reader NFC and the MIFARE tag to authorize or not to ignite the vehicle. Figure 8 shows the connection diagram used to make the contact signal, it will then be connected directly to the Shield Interface board, then it is necessary to perform a voltage regulation, since the Arduino Mega 2560 board handles levels of TTL voltage, this is achieved with the use of a voltage regulator LM7805, which allows a voltage input of maximum 25V [6], which in this case will be 12V, having as output a voltage of 5V.

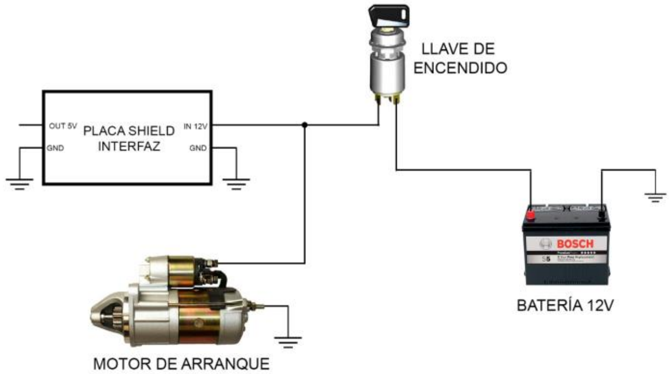

Fig. 8. Connection diagram of the vehicle ignition circuit to the Shield interface board.

The panic button block that is part of the Shield Interface board is also designed, this is mainly conformed by a button strategically installed in a hidden way where only the user of the vehicle knows its location, thereby avoiding the misuse of the same.

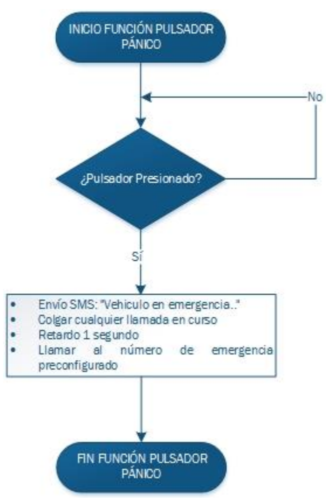

Fig. 9. Panic button flow diagram.

Figure 9 shows the flow diagram used for the panic button function, this indicates that the prototype first sends an alert SMS, then makes a call to a previously configured emergency number, as long as the panic button Has been pressed for two seconds.

Finally, for the Shield Interface board is designed to block the buzzer, this is very useful as it allows auditing informally the status of the vehicle for the different actions performed by the user.

TABLE III
Emission of different tones through the buzzer

N° beeps	Total length	Description
2	400ms	Correct energization of the prototype
2	1100ms	Correct initialization of all modules
3	300ms	Correct reception of the first GPS data
3	600ms	Authorization to activate and unblock the vehicle using Android application
		Correct reading of MIFARE tag

Table III shows the different sounds that are emitted by the buzzer in each action that the user makes.

After designing each of the blocks that make up the Shield Interface board, we proceed to elaborate the printed circuit that, through the interconnection of elements by means of tracks drawn manually by the Eagle software, end the design that will serve to later use it in the elaboration of bakelite.

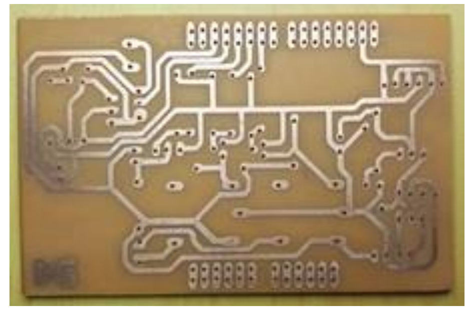

Fig. 10. Circuit board design of the Shield Interface board.

Figure 10 shows the final printed circuit with routed tracks, in this will proceed to weld the different elements that make up the Shield Interface board.

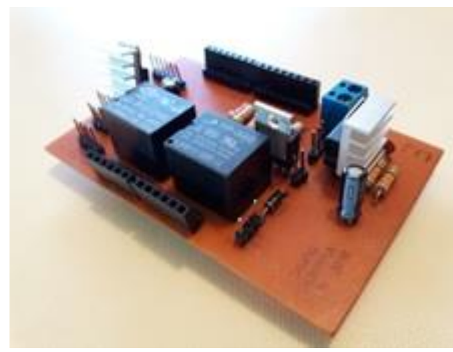

Fig. 11. Schematic elements of the Shield interface board.

Figure 11 shows the arrangement of already welded elements in the bakelite, thus allowing the use of the Shield Interface board.

C. GSM Communication System

The GSM Communication System for the prototype aims to transport the requests and responses that are generated both by the user through the Android application installed on the cell phone, as well as by the Control System which is formed primarily by the Arduino Mega 2560 is designed to recognize previously registered users based on cell phone numbers, which means that if the Android application were installed on another Smartphone that was not registered to the vehicle's system, the applications sent by the infiltrator, would be automatically rejected, this block is made up of the SIM900 GSM Shield Communication Module [7], which has a that the module inside has the possibility of inserting a SIM card.

Fig. 12. GPRS/GSM Shield v2 SIM900 module.

Figure 12 shows the physical form of the SIM900 GSM module used in the development of the prototype.

TABLE IV
Technical specifications GSM SIM900 module.

Characteristic	Detail
Operation Bands	850/900/1800/1900MHz
Supply voltage	5V
Energy consumption	Sleep Mode: 1,5mA Continuo: 500mA Maximum: 2A
Antenna	PCB external type
Power of transit	30dBm (1W)
Supported protocols	TCP/UDP
Serial communication	Variable, default 9600 baudios
Command set	Full control with AT commands
Headphones / Microphone	Jack 3.5mm 2 in 1
SIM	External Tray

Table IV shows the characteristics of the SIM900 GSM communication module. It can be highlighted that it has full compatibility with the Arduino Mega 2560 electronic development board, as the connection pins are easily adapted to the prototype design , also counts on an easy configuration since it is done through AT commands or through bookshops designed specifically for this module, in addition the power consumption, reduced size, quad support and the Jack 2 in 1 of headphones do the best Choice option as GSM communication module for use in the prototype to be developed.

D. Location System

The Location System is responsible for receiving the signals sent by the GPS satellites in orbit, this block receives this information periodically so that it is always available for when it is necessary to know the location of the vehicle, the information received is sent to Control System which processes and converts it into a predefined format, so that it can be sent to the user when requested, the request for localization by the user is done through the Android application installed on the Smartphone of the registered user to the system, once the request is made, the Control System through the GSM Communication System conformed by the GPS module NEO-6M [8], will send the response to the user in SMS format, showing a link to the GPS location , indicating also the speed of travel and height at sea level of the vehicle.

Fig. 13. GPS NEO-6M module.

Figure 13 shows the physical form of the NEO-6M GPS module used in the development of the prototype.

TABLA V
Technical specifications GPS NEO-6M module.

Characteristic	Detail
Comunicación	Serial (UART)
Supply voltage	3,3 – 6V
Energy consumption	Tracking: 30mA Acquisition: 45mA
Antenna	Active ceramics included
Status indicator	LED
Size	22x22mm (antenna) 23x30mm (module)
Frequency of data update	1Hz
Operating Limits	Altitude (18000m) Speed (515 m/s)
Sensitivity	Capture (-148dBm) Tracking (-161dBm)
Frequency of reception	L1 (1575,42 Mhz)
Operating temperature	-40 °C a 85 °C

Table V shows the most relevant features of the GPS module NEO-6M, where it is possible to emphasize that it is easy to acquire, it also provides a high performance thanks to its high sensitivity and operating temperature, allows to obtain latitude data , Length, speed, altitude, among others, information essential for the development of the project, on the other hand, has been designed to work with a low power consumption, in addition to being small size, the module perfectly adapts to the hardware of the prototype, due to the serial communication UART that it provides, finally, the power voltage that it needs for its operation is flexible and varies from 3.3V to 6V, given the characteristics presented above, this module becomes suitable for use in The elaboration of the prototype.

E. Power System

The Power System is responsible for supplying the necessary voltage to each of the devices and modules that make up the entire prototype, it is distributed in several stages, which fulfill a specific functionality. A special feature is one that allows the prototype to continue normal operation for the GPS function and the telephone call service in a time determined by the capacity of the backup battery, in case the main battery of the vehicle is disconnected.

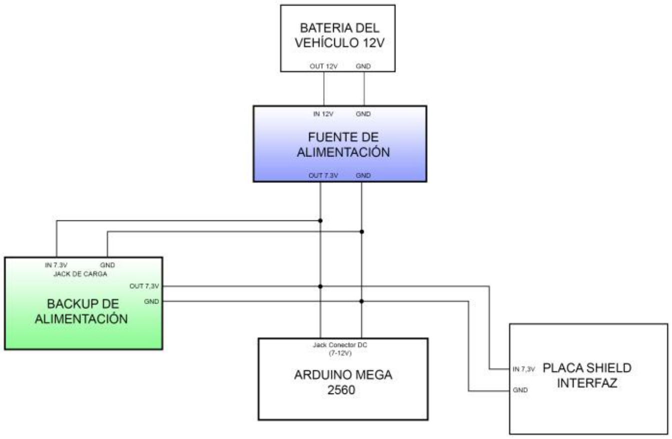

Fig. 14. Block Diagram of the Power system.

There are two stages that make up the entire power system, as described below:

- *Power supply*

The power supply is a very important stage, because it receives the voltage provided by the vehicle battery that is 12V, where it reduces it and regulates the voltage necessary for the operation of the prototype.

- *Power backup*

The power backup consists of a 7.4V lithium battery that is connected directly to the Control System and to the Shield Interface board.

1) Energy consumption analysis

In this section an analysis of energy consumption of the different devices that make up the entire prototype is performed. On the one hand, it will analyze the extreme case, in which all the devices are in full operation; On the other hand, the case when the main battery of the vehicle is disconnected.

- *Power consumption of the board Arduino Mega 2560*

For the case where the main battery of the 12V vehicle is connected, the analysis suggests, for the communication of the GSM, GPS and NFC modules it is necessary eight pins, where the sum of current consumption would result in 160mA in total; on the other hand the communication of the Shield Interface board requires six communication pins, resulting in a sum of currents of 120mA; finally the power of the GSM module is based on the Arduino board, then this is added 500mA, to finally result in a value of 780mA in the event that all the devices will be in full operation. Now, in case the main battery of the vehicle is disconnected, the power consumption is reduced, where for the communication of the GSM, GPS and NFC modules follow in the same way, but the pins that are connected to the shield Shield Interface would not come into operation, in order to finally have a current consumption of 660mA.

- *Power consumption of the Shield interface board*

The Shield Interface board has several devices connected, some of which are directly related to the control circuits of the vehicle, so it is necessary to analyze the two cases of operation; then for the case where the main battery of the vehicle is connected, the analysis suggests, for the activation of relays both to open or close doors, the power consumption is 70mA for each, giving a sum of 140mA; on the other hand, the automotive relay that serves to drive the gasoline pump has an energy consumption of 135mA; finally, the GPS module and NFC for its power consume an energy of 45mA and 120mA respectively, adding these two gives 165mA. Finally giving a sum of current consumption for the Shield Interface Board of 440mA.

Now, in case the main battery of the vehicle is disconnected, the relays for both opening and closing doors as well as for the operation of the petrol pump are inactive, since they operate at a voltage of 12V, then only the power supply for the GPS and NFC modules is in operation, finally giving a sum of current consumption for the Shield Interface board of 165mA.

- *Total power consumption of the prototype*

For the case where the main battery of the vehicle is placed, the following energy consumption is obtained, using equation 5:

$$\boldsymbol{Total\ Power\ Consumption}(\boldsymbol{bat\_12v}) = Arduino\ Mega\ 2560 + Shiel\ Interface\ Board \tag{5}$$

$$\boldsymbol{Total\ Power\ Consumption}(\boldsymbol{bat\_12v}) = 780mA + 440mA$$

$$\boldsymbol{Total\ Power\ Consumption}(\boldsymbol{bat\_12v}) = 1{,}220A$$

On the other hand, in the event that the main battery of the vehicle was disconnected and the power backup started to operate, it has:

$$\boldsymbol{Total\ Power\ Consumption}(\boldsymbol{bat\_lipo}) = 660mA + 165mA$$

$$\boldsymbol{Total\ Power\ Consumption}(\boldsymbol{bat\_lipo}) = 825mA$$

- *Total power consumption of the prototype in standby mode*

The power consumption is given in case the prototype is waiting for some action on the part of the user, then the power of the GSM, GPS and NFC modules have an energy consumption of 1.5mA, 45mA and 100mA respectively, giving a total power consumption of 146.5mA. In Arduino Mega 2560 board the GPS module communication pins are constantly functional since it sends periodic data to the board, then the power consumption would be 40mA, since each pin consumes 20mA.

$$\boldsymbol{Total\ energy\ consumption\ stand\ by} = 1{,}5mA + 45mA + 100mA + 40mA$$

$$\boldsymbol{Total\ energy\ consumption\ stand\ by} = 186{,}5mA$$

2) *Power Supply*

After performing the analysis of energy consumption by the prototype, then it is necessary to make the choice of the voltage regulator module, since it is responsible for supplying the voltage and current needed to operate the majority of devices involved in the prototype, therefore, it is imperative that the module supplies the necessary current, thus avoiding overheating and thus any possible damage.

Fig. 15. LM2596s voltage regulator module.

Figure 15 shows the voltage regulator module based on the integrated circuit LM2596s [9].

TABLE VI
Technical Specifications LM2596s voltage regulator module.

Characteristic	Detail
Output Voltage Range	1,2V a 37V
Max Input Voltage	40V
Output current load	3.0A
Input voltage	Up to 40V
Stand-by current consumption	Typically 80µA
Types of packaging	TO-220, TO-223
Protections	Current limit and thermal shutdown
Size	45 (Length) x 20 (Width) x 14 (Height) mm
Price	$5

Table VI shows the characteristics of the voltage regulating module LM2596s, where it is highlighted that the output current load is 3A and satisfies the energy consumption analysis performed previously, in addition, its small size, the low consumption in standby, make this module the best option as a power source in the development of the prototype.

3) *Power backup*

On the other hand, for the correct choice of the characteristics of the battery that is going to be used as backup stage the following points must be taken into account:

- *Voltage of the battery*: The voltage that will have the battery is of 7.4V, value determined by the input voltage corresponding to the power Jack of the electronic development board Arduino Mega 2560 which is between 7 to 12V, all this since this plate conforms the Control System and also feeds the GSM module directly; on the other hand the battery also supplies the necessary voltage to the Shield Interface plate, specifically to the 3.3V voltage regulator circuit, which supplies the power to the GPS and NFC module.
- *Battery capacity*: The battery capacity is determined after the previous analysis of power consumption of the different devices that will be fed to the backup stage. For the present project was made the choice of a battery with a capacity of 2000mAh, all this since this value meets the requirements of energy consumption analyzed previously and also has a considerable margin of safety against possible overloads.

Fig. 16. 7,4V LIPO battery.

The backup battery used is shown in figure 16, in addition in Table VII it is possible to observe the characteristics of the same presented by the manufacturer.

TABLE VII
Technical Specifications LIPO battery.

Characteristic	Detail
Voltage	7,4V
Battery Capacity	2000mAh
Download speed	25C

4) *Backup battery life time*

There is a general formula that allows the calculation of the battery life time, which is shown in equation 6.

$$\boldsymbol{Time\ duration}(\boldsymbol{min}) = \frac{Battery\ Capacity(Amp * min)}{Discharge\ Speed(Amp)} \quad (6)$$

It is known that the capacity of the battery used for the present project has a value of 2000mAh, then this capacity must be converted to Amperes per minute, then you have:

$$\boldsymbol{Battery\ Capacity} = 2A * 60min$$
$$\boldsymbol{Battery\ Capacity} = 120\ (Amp * min)$$

On the other hand, the discharge rate of the battery in units of amps is given by equation 7.

$$\boldsymbol{Download\ speed}\ (\boldsymbol{A}) = \text{Download speed} * \text{Capacidad}\ (A) \quad (7)$$
$$\boldsymbol{Download\ speed}\ (\boldsymbol{A}) = 25 * 2\text{A}$$
$$\boldsymbol{Download\ speed}\ (\boldsymbol{A}) = 50\text{A}$$

Then the time that will last the battery supplying the current of maximum consumption is obtained by replacing the data previously calculated in equation 6:

$$\textbf{\textit{Time duration}}(\textbf{\textit{min}}) = \frac{120\ (Amp * min)}{50\ (Amp)}$$
$$\textbf{\textit{Time duration}}(\textbf{\textit{min}}) = 2{,}4\ min$$

As a result, a value of 2.4 minutes is obtained continuously, supplying the maximum consumption current, but this is a theoretical maximum current that the battery is capable of supplying; on the other hand, there is the actual current that the battery is going to supply at any moment and it will be the one that the circuit requests in each action that is performed. Finally, after having performed the energy consumption analysis of the devices that will be connected to the backup system in the event that the main battery of the vehicle is disconnected, the approximate value of total energy consumption of the prototype, which is 825mA, in the case of normal full operation; on the other hand, in standby mode, the energy consumption considerably reduces to a value of 186.5mA; given these values a battery run time can be obtained for the normal operating mode of about 2.42 hours, as follows:

$$\textbf{\textit{Time duration}}(\textbf{\textit{normal}}) = \frac{2000\text{mAh}}{825\text{mA}}$$
$$\textbf{\textit{TTime duration}}(\textbf{\textit{normal}}) = 2{,}42\ horas$$

Finally, for stand-by mode, the battery run time is about 10.72 hours, as described below:

$$\textbf{\textit{Time duration}}(\textbf{\textit{stand by}}) = \frac{2000\text{mAh}}{186{,}5\text{mA}}$$
$$\textbf{\textit{Time duration}}(\textbf{\textit{stand by}}) = 10{,}72\ horas$$

After the design of each block that make up the prototype, proceed to present the general electric diagram of the prototype, which can be seen in figure 17.

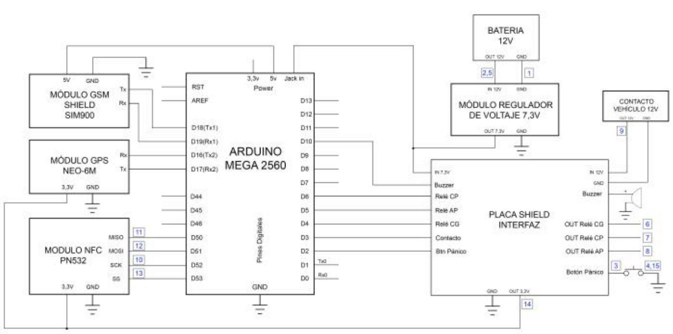

Fig. 17. General electrical diagram of the vehicle location and safety system prototype.

F. Android Application

The Android application "NeoTrack", allows the registered user to the system with the cell number, to have the opportunity to have control of the different resources that the prototype offers, the communication that occurs between the user with the application and the prototype installed inside the Vehicle is provided by GSM technology. To make the design of the application was made use of the environment of development for Android applications, which is named App Inventor 2 Beta, for the use of the tool is strictly necessary to create an account on Google and thus to make use of the benefits that the platform offers.

Figure 18 shows the designer sector, where all the visual part that the application is going to have is elaborated

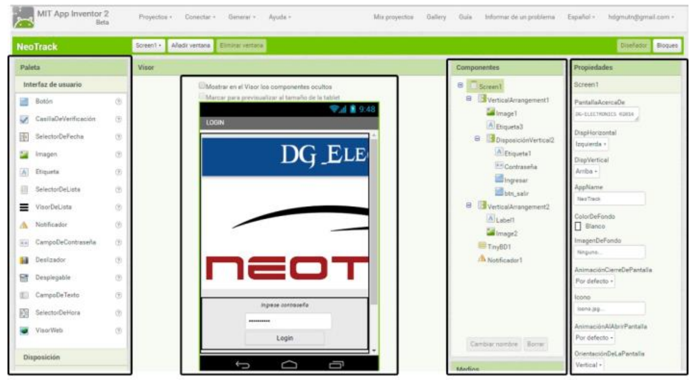

Fig. 18. Design Sector App Inventor 2 Beta.

The application is distributed in three screens, each one of which fulfills a specific function, Figure 19 allows a better understanding of the above.

Fig. 19. Screens of the Android application.

The design of the application is done in the block editor sector, which can be seen in figure 20.

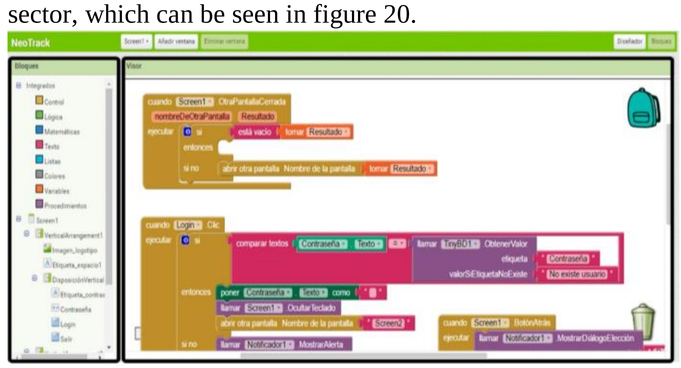

Fig. 20. Sector editor of blocks App Inventor 2 Beta.

1) Programming Login Screen

The block programming phase of the Login Screen is shown in Figure 21.

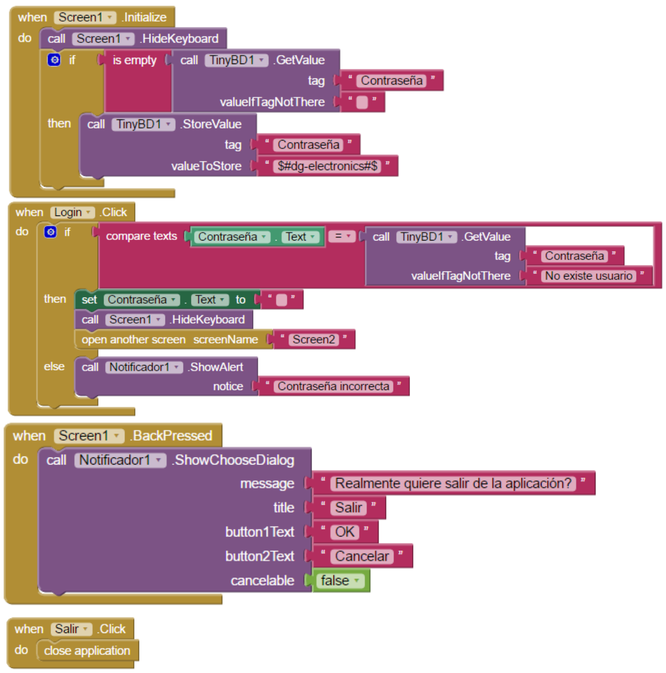

Fig. 21. Block Programming of the Login Screen.

2) Schedule Action Screen

Block programming of the Action Screen is shown in Figure 22.

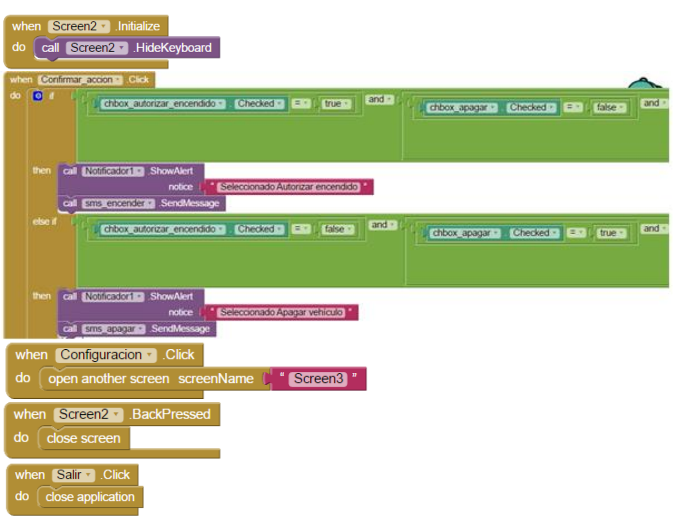

Fig. 22. Block Programming of the Actions Screen.

3) Settings Configuration Screen

The block programming of the Configuration Screen is shown in Figure 23.

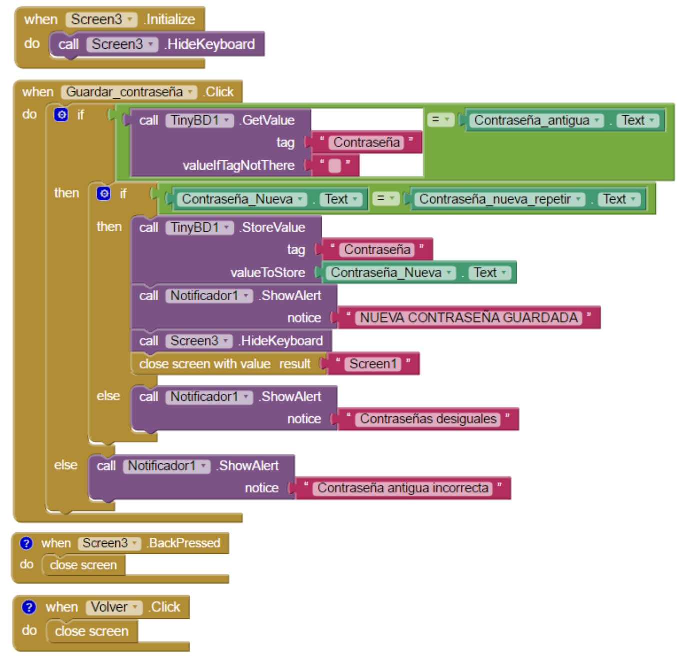

Fig. 23. Block programming of the Configuration Screen.

III. RESULTS AND DISCUSSION

A. Description of the implemented prototype

The prototype is built by several blocks that are conformed in turn by electronic devices that allow the correct operation of the same, it has a cell phone number stored on a SIM card, the system can be installed in any motor vehicle, provides the opportunity to the owner registered previously, to have a system which allows to know the GPS location and also to have control of several of the vehicle's resources, which can be controlled locally or remotely. The location of the vehicle is achieved thanks to the GPS receiver module, which allows the user to request the prototype based on an Android application, to know the location, altitude at sea level and speed of travel of the vehicle, thanks to the reception of an SMS text message sent by the prototype to the requester with such information. The ignition control of the vehicle is based on user authentication by reading a MIFARE tag through an NFC reader, in addition to sending an SMS text message confirming that action to the user. On the other hand, by means of an Android application the user can control the different resources of the vehicle of remote way by means of a Smartphone and a cellular number previously registered to the system; plus, the strategically installed panic button that, when pressed, makes an emergency call to a pre-configured number, allowing you to hear the conversation taking place inside the vehicle.

Figure 24 shows the bakelite that makes up the Shield Interface board, in Figure 25 the prototype is shown ready to make the corresponding connections in the vehicle, and Figure 26 shows the wiring made from the prototype to the systems to be controlled in the vehicle.

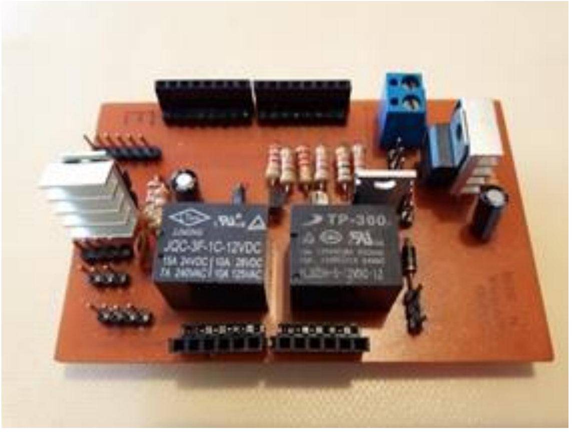

Fig. 24. Shield Interface Board.

Fig. 25. Interior of the prototype installed inside the vehicle.

Fig. 26. Wiring from the prototype to the vehicle.

B. *Implementation and functional tests*

For the implementation of the prototype was made use of a Renault Sandero 2012 car as shown in figure 27, this has a factory installed central locking system of doors, which the prototype will control, in addition in the internal part of the sufficient space, which facilitates implementation work.

Fig. 27. Renault Sandero 2012.

After performing the main power interconnection from the vehicle battery, it is proceeded to install each of the devices that will go inside the vehicle, which will be connected to the prototype, these are, microphone, NFC reader, panic button and the USB cable, on the other hand, in figure 28 the interconnection of the cables carrying the different control signals of the central locking of the vehicle can be observed.

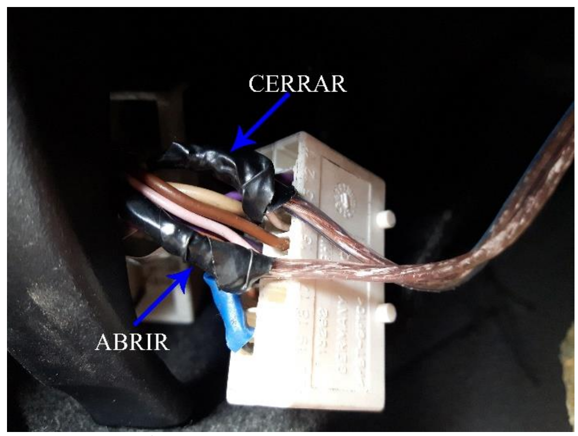

Fig. 28. Connection of the central locking signals.

As a last step, the interconnection of the different cables that carried the signals that control the operation of the gasoline pump was made, this is also conformed by a fuse of 5A used to prevent possible damages by overloads. In addition, the cable carrying the contact signal was connected as shown in figure 29.

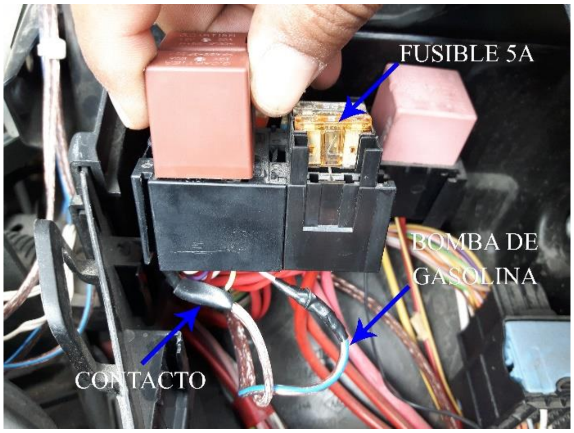

Fig. 29. Connection of the petrol pump and vehicle contact signals.

The tests of operation were made locally for the functions of authorization of ignition and panic button, in addition the tests were carried out from the Android application remotely for the functions presented by the prototype, which can be observed in the figure 30.

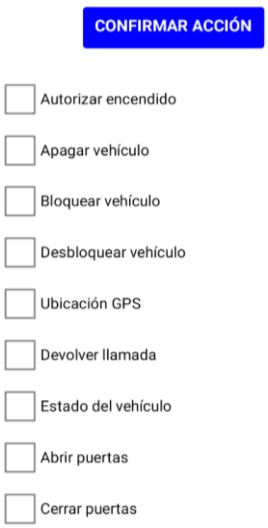

Fig. 30. Interface of the screen of actions of the Android application.

The "Autorizar encendido" action is used in the event that the user wishes to authorize the ignition of the vehicle without the MIFARE tag used for the said process, "Apagar vehículo" is used to remove the power to the petrol pump and as a result the vehicle will be switched off, "Bloquear vehículo" is used in case it is desired to block the manual activation function from inside the vehicle with the MIFARE tag, allowing to authorize the ignition only from the Android application, "Desbloquear vehículo", returns the vehicle to the normal operating state, "Ubicación GPS" allows to know the location of the vehicle by receiving an SMS with information similar to that shown in Figure 31.

Fig. 31. GPS location SMS information.

The web link can be opened via a browser online, or through a map application offline as shown in figure 32. On the other hand, the action "Devolver llamada" allows to make a request to the prototype that this make a call to the requesting number with the possibility of hearing the conversation taking place inside the vehicle, the action "Estado del vehículo" allows to receive a message in SMS format showing information similar to that shown in figure 33. The action "Abrir puertas" allows to activate the central locking of the vehicle, thus allowing to unlock the door locks; Finally, the action "Cerrar puertas" allows locking the locks on the vehicle doors.

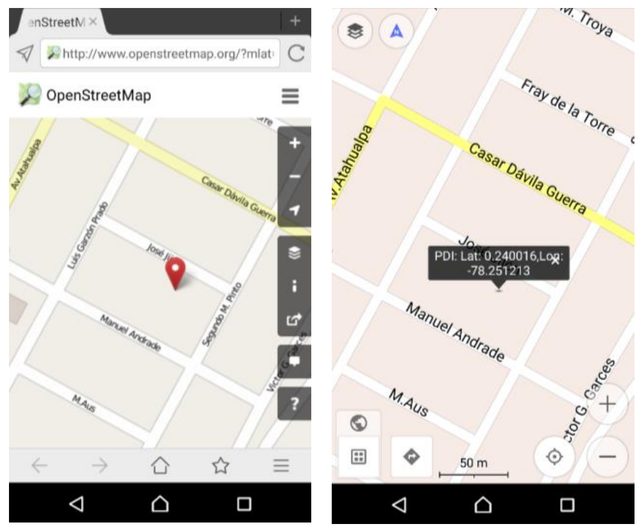

Fig. 32. Example WEB link opened with a web browser (left), or OsmAnd + application (right).

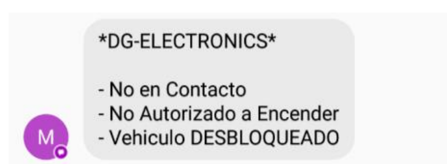

Fig. 33. SMS status information of the vehicle.

IV. Conclusions

- The developed prototype will allow the owner of a vehicle to have an intelligent system since it uses devices with the latest technology that allows to offer remote services, also offering advanced security features since it is based on NFC technology, offering encryption of cards or keypads Identification so that they cannot be cloned, thus providing the user with comfort and tranquility.
- The prototype system of location and vehicular security

was made taking the best design features of the security systems offered by the Ecuadorian market, all this after having elaborated a previous analysis, allowing in this way to have a prototype with state-of-the-art technology.

- An analysis of the open-source technologies available in the Ecuadorian market was made, allowing, on this basis, to make the correct choice of the Arduino Mega 2560 electronic development board.
- The study of the technologies in GPS, GSM and NFC communications involved in the development of the prototype was carried out so that an efficient system could be developed, complying with the communication protocols used by the different electronic modules.
- The Shield Interface board was designed, which is a card that allows to obtain a more reliable communication between the Control System and the different systems that are controlled within the vehicle, thus generating considerable space savings, returning to circuitry a lot more compact.
- The Android application "NeoTrack" was developed in the platform "App Inventor", which is based on a graphical environment and programming is based on blocks, thus facilitating the design to the programmer considerably, the application complies with both parameters Security at the moment of entering it, counting on an authentication system, as well as having all the characteristics that the prototype offers, being shown in list form, facilitating the operation to the user of the vehicle.
- The user manual of the vehicle location and safety system, gives the owner of the vehicle an ease of use and understanding of the features it offers, thus generating the correct use of the prototype; on the other hand, an installer's manual was developed, allowing the prototype to be installed effectively and correctly thanks to its easy-to-understand electrical and block diagrams, guaranteeing efficient operation of the prototype.
- In the design of the power supplies it is essential to calculate the thermal coefficient θ_{JA}, for the prototype a value of $\boldsymbol{\theta_{JA}} = 151{,}51\ {}^{\circ}\mathrm{C}/_{W}$ was obtained, then the manufacturer indicates that if the calculated value is greater than that presented in the datasheet, the use of an external heatsink is not required.
- The developed prototype offers an important feature of vehicle security, which is, if the user has made a blocking of the prototype for some situation based on the Android application, the vehicle remains in that state unconditionally until the user does the action The vehicle battery has been disconnected and reconnected.

V. RECOMMENDATIONS

- The present project of prototype of system of location and vehicle safety is a beginning for future improvements of the same, then the main recommendation is to continue the investigation, innovating with the possibility to improve the benefits of this one currently offers, all this is possible thanks that the project developed is based on the open-source platform in both hardware and software.
- For future designs in which this prototype serves as the basis of execution, it is recommended to migrate to GPRS technology in order to make use of a data plan and execute all the actions offered by the prototype based on the Internet, all this since the Infrastructure is provided to carry out this process.
- The implementation of the system inside the vehicle must be in a place of difficult access for anyone, to avoid any manipulation. However, the panic button must be in a non-visible location but accessible to the user.
- Train users of the system with the aim that they know each one of the characteristics that it offers, so that they can make correct use of the prototype.
- At the moment of implementing the prototype, make the connections in a correct and orderly manner, avoiding also having bare wires as they could lead to short circuits.
- For GPS location and emergency call functions, regardless of the chosen cellular telephone operator, it is recommended to constantly check and maintain the prototype with balance and SMS message package, since these two characteristics are indispensable to provide a localization system and optimal vehicle safety for the user.
- Set a locking pattern or password for the smartphone, as this will give a greater guarantee of security to the system, preventing in this way that anyone tries to manipulate the Android application and can get to make use of the functions that it offers.
- Register a second cellular number to the vehicle system in conjunction with the installation of the Android application, this being the case in case the smartphone that bears the number of the main user of the vehicle is lost, then the new user will keep the same [1] Priorities than the main user and can perform all the actions offered by the prototype.
- For the registration of the emergency number that will be configured by the developer, it is recommended that the smartphone assigned to this number is one that has an always active line, all this being of vital importance since it will record the audio of Automatically when there is an emergency situation.

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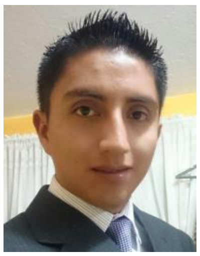

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