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Design of an Electronic Bracelet for Remote Surveillance of People Deprived of their Freedom in Colombia

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Abstract

This paper establishes a proposal for the design of a bracelet prototype for electronic surveillance, based on the design of two functional blocks composed of an electronic module and an ergonomic mechanical structure. The 3D modeling of the mechanical structure is shown, ensuring that it is safe and resistant, in addition the distribution of the electronic components can be observed, which are perfectly well placed inside. Regarding the electronic design, a solution is proposed using a GPS of low consumption and cost for the location of the device, a GSM module for data transmission and constant monitoring, in addition to this, the device must store the location data, time and date in a local storage module and must also monitor the power of the device to ensure the proper functioning of the system.

Keywords: GPS, Electronic Surveillance, GSM, Bracelet.

INTRODUCTION

When talking about devices for monitoring people, it can be found a wide variety of products in the market associated with this function. It is possible to find applications for mobile devices, smart watches, belt accessories, key chains and many other elements [1-3] [9]. These commercial solutions are linked to multiple needs, it can be found solutions regarding surveillance and security topics, support for sports activities, support for the care of sick people (Alzheimer's disease, Parkinson and Lewy body dementia), etc [4]. Within these needs there is an institution of Colombian society that seeks a technological solution that can be efficiently adapted to their requirements; this entity is the National Penitentiary and Prison Institute (INPEC for its Spanish initials), with its electronic surveillance program.

The electronic surveillance system is a set of means of remote control that can be put at the service of criminal justice. In addition, it is a set of mechanisms that aim to reduce the levels of incarceration [5], to increase the surveillance of persons prosecuted or convicted, to reduce the costs of controlling some criminal measures and to reduce the recidivism of those sentenced ones; keeping in mind those aspects, it is interesting to study the application and development that can be achieved by the massification of electronic surveillance, in order not only to decongest the prisons, but also to allow the convicted people early re-socialization, maintaining their current employment or ability to work, family and social ties, introducing greater personal discipline in their lives and avoiding the criminogenic effects of prison [5] [6].

This paper establishes a proposal for the design of a bracelet prototype for electronic surveillance, based on the design of two functional blocks composed of an electronic module and an ergonomic mechanical structure. In the development of the document it can be seen the two main blocks by which the prototype is formed, the mechanical structure and electronic components; additionally it can be found a series of recommendations associated with the ideal characteristics that the design must have according to the performed research.

PROPOSED WORK

It is proposed to develop a device that can be used as a bracelet or anklet. This device can transmit the position of the monitored person through mobile network [10]. As a security system and detection of anomalous activities in the structure of the bracelet, this design provides the use of fiber optic wires guaranteeing alerts notifications associated with the manipulation and undue alteration of the device.

Mechanical structure

By regulation the bracelet must be 100% hypoallergenic, so it is proposed to use thermoplastic elastomer materials, or also known as TPE. The TPEs are in the category of polymers (generally a plastic and a rubber) that lead to elements with thermoplastic and elastomeric characteristics. The common elastomers, such as the family of silicones, rubber-rubber, polyurethane foams, among others, are thermosetting; thermoplastic elastomers are very easy to use in manufacturing. The proposed design can be seen in Fig. 1.

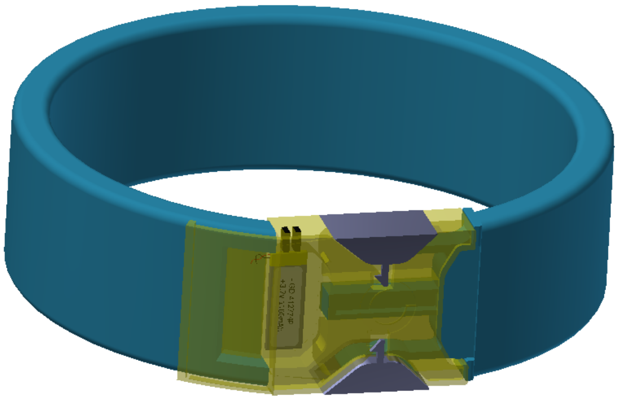

Figure 1: Three-dimensional bracelet design.

In order to provide reliability to the security and integrity of the bracelet, the mechanical design of the bracelet has two security plates, see Fig. 2. Each security plate has a tab at its upper end which develops a firm connection with the device. The only way to open the handle results from the fracture of the security plates.

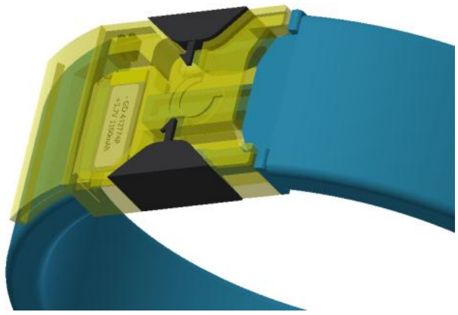

Figure 2: Security plates (black color).

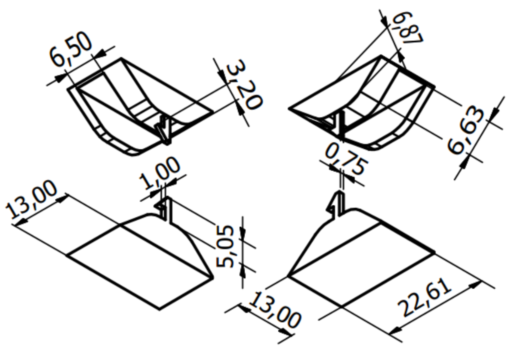

Figure 3: Dimensioned design Safety plates.

The end of the handle is responsible for ensuring the installation of the device, see Fig.4, this fastening clip has three terminals; the first and third terminals allow to establish the permanent union of the end with the main device, so that the only option to separate them is by means of the fracture of the security plates. On the other hand, the second terminal is responsible for ensuring that the optical fiber surrounding the bracelet has a perfect connection with the final electronic circuit.

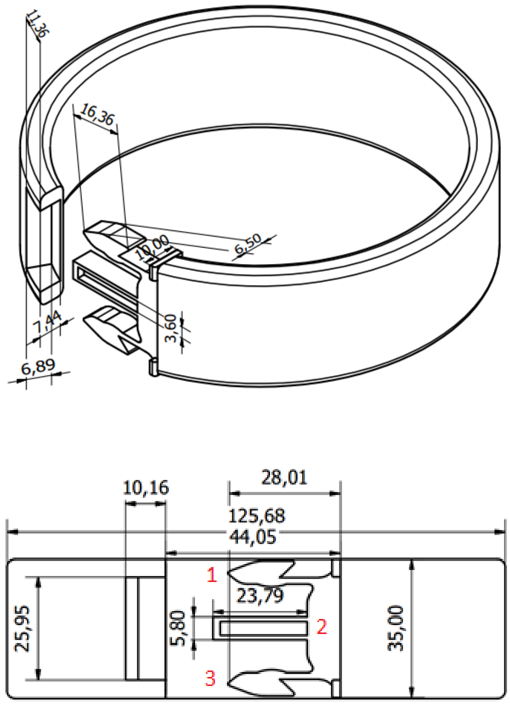

Figure 4: Connection Terminals

Electronic design

The proposed system basically consists of 6 functional blocks (see Fig. 5) which are:

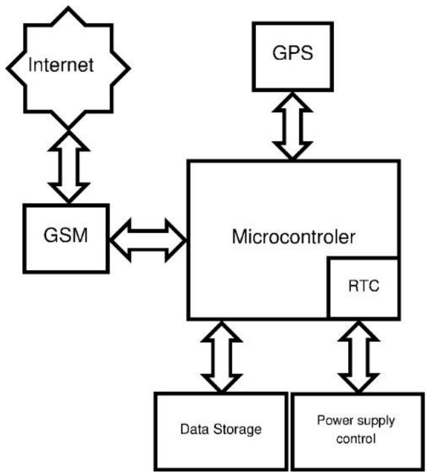

Figure 5: Electronic architecture block diagram

GPS Global Positioning System Technology

For the prototype design it is necessary to take into account the available bracelet size since it must be small enough to be transported without any problem, in addition to an embedded antenna; for this reason the use of an embedded GPS UP501 satellite receiver is considered. Its measurements 22.0 x 22.0 x 8 mm make it perfect for the proposed prototype, see Fig. 6.

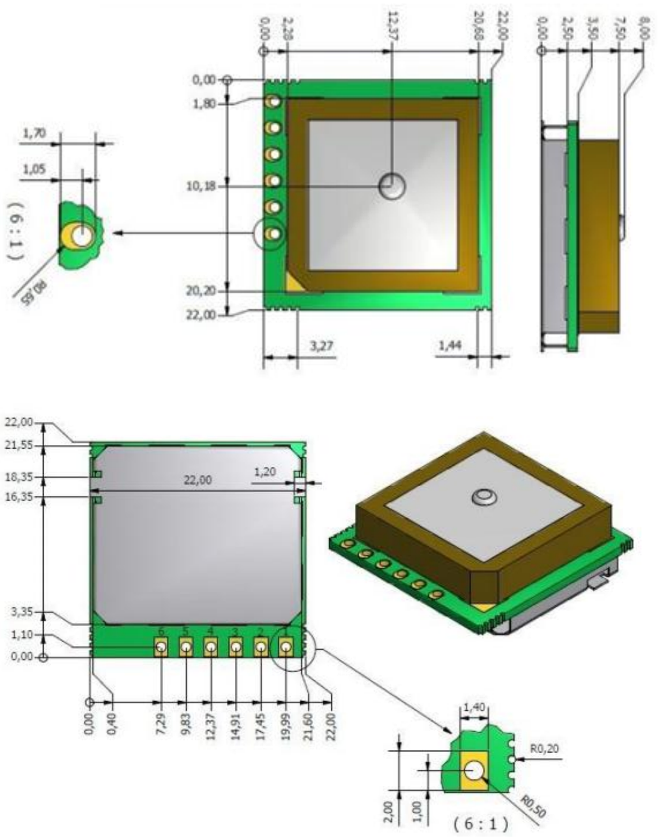

Figure 6: Bounded measurements Fastrax UP501 [7].

The encapsulation provides a fast TTFF (Time to First Fix), which is a detailed specification of the time required by a GPS receiver to acquire a position. It connects to any application through a serial port which uses CMOS voltage levels.

Operation Modes

During turning on, the device boots from the internal flash memory for normal operation.

• *Tracking / navigation mode*

In tracking / navigation mode, the receiving module searches for additional satellites and collect almanac data. Once it has collected almanac data (this takes approximately 12 minutes from a Cold Start), it will enter to low power tracking mode.

• *Low power tracking / navigation mode*

The receiver continues with normal navigation, but does not collect more almanac data. Therefore, the current consumption is reduced to a level of <75 mW (<85 mW for UP501 R with predetermined UART baud rate).

• *Backup mode*

When the operating voltage is removed, the module enters to backup mode.

The module keeps the timing by the RTC oscillator. In addition, the satellite ephemeris data is stored in backup battery RAM to obtain fast TTFF when VDD is connected again. Any user configuration is also valid as long as the backup supply VDD_B is active. When the VDD_B is off, the configuration is restored to the factory settings during the next power on.

Technology System for GSM Mobile Communications

Figure 7: GM862 GSM module [8].

In order to restrict the maximum size of the prototype, the use of Telit's GM862 quad band module is proposed, with dimensions of 43.9x43.9x6mm. This small module can be used anywhere in the world where cell phones are used; it is compatible with 850/900/1800/1900 MHz frequencies of mobile networks worldwide.

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Table 1: GSM module operating frequencies

TYPE	TX Frequency (MHz)	TX Frequency (MHz)	# Channels	Space TX-RX (MHz)
GSM-900	890.0-914.8	935.0-959.8	0-124	45
GSM-900	880.2-889.8	925.2-934.8	975-1023	45
GSM-850	824.2-848.8	969.2-893.8	128-251	45
DCS-1800	1710.2-1784.8	1805.2-1879.8	512-885	95
PCS-1900	1850.2-1909.8	1930.2-1989.8	512-810	80

The GM862 module is controlled through AT commands. Meaning that, to make a call it is only necessary to send a string of characters such as "ATD 3035553795". The characteristics associated with their operating frequencies can be seen in Table 1.

Power consumption, transmission power:

The GSM modules for the 850 and 900 frequency bands have a nominal RF peak power of 2 W, or + 33dBm at 50 Ohm. On the other hand, the modules for the 1800 and 1900 bands have a nominal RF peak power of 1 W, or + 30dBm at 50 Ohm. The GM-862 device has a power consumption according to Table 2.

Table 2: Current consumption module GM862

Shutdown Current	$< 26uA$
Operating Current (Voice Channel)	$250mA \pm 20\%$ (RMS)
Current in Stand By	$< 17mA$ (RMS)

Transmission and reception of data:

The GSM module has the ability to transmit and receive data via serial port through the use of AT Hayes commands. These commands are expressed by ASCII codes and are translated by the system as they are entered, see Table 3. When the system receives the command, it responds with an OK to the transmitter. AT Hayes commands usually start with: AT + (Command) + <CR>, where <CR> implies an Enter to the system.

Table 3: AT commands for the GM862 module

Command	**Description**
ATA	Device in response mode
ATE	Turn ON/OFF command echo
ATDP	Pulse voice dial
ATDT	Tone voice dial
ATH	Perform line interruption
ATL	Speaker volume control
ATN	Set the device speed in function to the terminal
ATQ	Error messages control
ATZ	Device initialization

Electronic Control Unit

This operating block is based on a microcontroller which is responsible for performing the reception and processing of the information delivered by the GPS module; in the same way it is responsible for communicating with the GSM modem by RS232 protocol. For the logic of the Tracking System, the following reasoning arises:

1. The GPS module obtains the satellite data
2. Reading the data through the microcontroller through the UART port
3. The microcontroller will enter a loop for reading information obtained by GPS
4. If an interruption occurs when receiving the call from the mobile, it will save the last data obtained by the GPS.
5. The information that arrives from the GSM is processed, translating the information obtained in NMEA commands to AT commands.
6. The location information of the system is sent to the corresponding receiver or information base.
7. The extraction of GPS data can be executed by means of PIC serial communication

RESULTS

The proposed design provides a set of elements that make this a functional device that can be adapted in diverse situations where the monitoring process is necessary. The development of this research allowed finding the most relevant characteristics that a product associated with Electronic Surveillance must have; these recommendations are shown in the table 4-

CONCLUSIONS

The conceptual design developed proved to be an effective solution to the needs found in the electronic surveillance program of the National Penitentiary and Prison Institute (INPEC for its Spanish initials); it was achieved the proposed solution to be robust and resistant to any possible vulnerability in its infrastructure, through the implementation of a novel technique in terms of the identification of ruptures or undue openings of the bracelet, thus achieving a practical and functional tool that can be placed at the service of the needs of Colombian criminal justice and any other entity that requires the monitoring of people in real time.

Table 4: Ideal characteristics for monitoring bracelets

BRACELET	Dimensions	9.65 x 5.334 x 2.286 cm	
	Weight	68gr without belt	
		124,7gr including belt	
	Normativity	Impermeability	Waterproof IP68 (total immersion in water at 5 m for 1 hour)
		Thermic	EN 60068: Storage at 70 ° C
			EN 60068: Operating at 55 ° C
		RF fields	Certification that the RF fields do not produce adverse effects on health (FCC-15-A, 2004/40 / EC)
		Batteries	Battery security (UL1642, IEC62133, UL2054)
		Shock / Impact Test	EN 60068 - Drop test of 1 m on steel plate
	Material	Hypoallergenic	
	Anti-handling	Optic fiber in the bracelet	
	Belt	Re-adjustable	
Power source	Battery	USB or mini USB port and/or waterproof socket for electric charge	
		The power supply contains internal surge protectors and overloads	
		Wireless charger	
		Inside Lithium battery (Li-Ion)	
		Minimum duration of 72 hours in use	
		Minimum duration of 6 months in stand-by	
Events	Storage	Ability to store more than 3,000 events (geo location points inside the bracelet)	

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