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Pet Tracker

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***Abstract*—** Lots of animals get lost every day. Many of them could have been found if they would just wear some kind of tracking device. Thanks to the benefits of the modern engineering, we were able to create a device that solves this problem. After analysing already existing similar products, we have decided to add extra features to stand out among competitors. Combining GPS and GSM technology, we can accurately locate a pet and show it on Google Maps within a minute, offering and activity monitoring system at the same time. This paper describes the whole development process of the Pet Tracker.

***Keywords*—**Activity, monitoring, pet, tracking

I. INTRODUCTION

THE main objective is to design and develop a pet tracking system. We wanted to stand out among other competitors and we decided to add an activity monitoring feature. Once the main objective is fulfilled, to create a unique environment for the pet owner where functionalities meets the needs, and every user finds whatever he is looking for.

We had to create a product for our client and the following requirements must be taken into consideration:

1. Web interface;
2. Display track using Google Maps/Google Earth;
3. On board data storage;
4. Data download Interface;
5. Light, small, portable, wearable device;
6. At least 48 h Power autonomy;
7. Use open source technologies;
8. Comply with the following EU Directives:
   I. Machine Directive (2006/42/CE 2006-05-17);
   II. Electrical Safety: Low Level Voltage Directive (2006/95/CE 2006-12-12);
   III. Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27);
9. Mandatory adoption and use of the International System of Units (The NIST International Guide for the use of the International System of Units)

In order to fulfil the expectations of our client we followed the requirements and we added a unique feature – an activity monitoring system. Although we encountered some problems during the project we managed to build well-working system. The main problem was to get all the materials which were necessary to finish the task.

II. STATE OF THE ART

In the process of designing this product there are many aspects to take in consideration. The major ones are the location system, a mean of communication, the power supply and a system controlling device. This chapter will present the most relevant systems and technologies that can be used to build a pet tracker, conclusion of why we chose certain technologies and also present some products offering similar features to our pet tracker.

A. Technologies

1) Microcontroller

A microcontroller is a programmable integrated circuit, capable of executing commands stored in its memory. It is used to control and automate electronic and electro-mechanic systems. Due to future references on single-board microcontroller (or development board), the present exposition will refer to such products. A single-board microcontroller is a microcontroller built onto a single printed circuit board [1], PCB. We can find a wide quantity of such products in the market but they all have the same common aspects: microcontroller, Input/output circuits, clock generator, RAM – Random-Access Memory and stored program memory. These devices are typically low-cost and very effective, offering an easy way to evaluate microcontroller chips.

a) Arduino Pro Mini

Based on the ATmega168, it has 14 digital input/output pins, 6 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers [2]. This board is intended for semi-permanent installation in objects or exhibitions, and it is suitable for small projects that do not require large processing capabilities.

2) Wireless Communication

With a strong presence in our society, wireless systems allow us to transfer information, communicate, between two or more points that are not connected by an electrical conductor [3]. There are many ways of communicating without any wires but there are some that have a growing impact in our lives.

a) GSM/GPRS Modules

These modules are used in the mobile phone industry as the main communication device. The range of these devices is restricted by the presence of telecommunication antennas, but there is coverage for this network anywhere one can use a mobile phone. The GSM standard was developed as a replacement for first generation analog cellular networks, and originally described a digital, circuit switched network optimized for full duplex voice telephony. This was expanded over time to include data communications, first by circuit switched transport and then packet data transport via GPRS [4], [5].

3) Location System

There are many approaches when it comes to location, one can think of a street, a room or a remote spot on the desert. In this project, location refers to geographic coordinates (latitude, longitude and altitude). There are many ways to determine location using navigation tools, being the most commonly divulged the Global Navigation Satellite System, GNSS. It is also possible to determine one's position using radar (Radio Detection and Ranging), GSM (Global System for Mobile Communications), Wi-Fi and other radio tools.

a) GNSS

This system makes use of artificial satellites that transmit time signals and allow electronic receivers to determine latitude, longitude and altitude [6]. There are operational GNSSs in the United States (Global Positioning System - GPS) and Russia (Globalnaya Navigatsionnaya Sputnikovaya Sistema - GLONASS). Some other systems are being developed in China (Compass) and Europe (Galileu). These systems are typically used in tracking and navigation and are becoming more established in our society every day. This is an accurate and reliable location system when used outdoors.

b) GSM

Even though this is not directly a location system, the mobile device industry has turned it into one. This technology makes use of the nearby telecommunication antennas to determine the GSM module's location – using multilateration. This technology does not present considerable limitations when it comes to indoors use, but its accuracy relies on the number of telecommunication antennas nearby.

4) Battery

A battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy [7] and vice versa. This device can either be rechargeable or not, and this project has in consideration the ecological footprint, the mid/long term economic and maintenance concerns as well as the consumer's comfort, hence the use of rechargeable batteries. This narrows the types of batteries and battery chemistries to study.

a) Li-ion

Emerged in the early 90's, it has a high energy density, a relatively low self-discharge rate, no need for maintenance as well as the ability to provide high current to a system. This type of battery has some limitations, mainly in its maturity and the requirement of a protection circuit in order to maintain the voltage and current within the safe limits [8]. The Lithium ion chemistry is lightweight, does not contain toxic metals like the lead acid batteries and lasts long enough to span the typical life of the product.

B. Conclusions

We decided to design a quality product that is reliable and accurate as well as economical and practical. To make this possible we selected a GPS module, a GSM/GPRS module, an Arduino Pro Mini single-board microcontroller and a Li-ion battery to power everything up.

The GPS's choice is related to its accuracy and cost. To balance its limitations we are also using a GSM module to cover the indoor location and to provide an independent communication mean.

To control the system we decided to use the Arduino Pro Mini at 8 MHz because we are not looking for extreme frequency processors and it is small enough to fit in a pet collar. The lower frequency also reflects in the power consumption of the controller. To power up the system we chose a Li-ion battery due to its specific energy, cell voltage and cycle life characteristics.

C. Related products

There are several products that allow a pet owner to track its pet. We have studied two different types of products and labelled them by their operating range (or communication system). These devices use GPS or GSM to acquire one's pet location, and communicate with the owner using either the GSM/GPRS network or a RF transceiver pair.

The GSM/GPRS network ranged pet tracking devices allow the owners more freedom since they can just use the

manufacturer's interface to monitor and track the pet, by simply using a smartphone or a computer, therefore excluding the need to purchase a specially designed handheld device.

The range of these devices depends on how much the telecommunication industry is developed in one particular area.

When it comes to accuracy, although many use the name GPS in their product name, a GPS module is not included in the device so it can be imprecise due to its dependency on the telecommunication antennas, needed to calculate the position based on multilateration. When the GPS module is used, the device becomes more accurate but it also reduces the device's power autonomy. The price of this type of device is fairly low, but it is required the payment of a monthly fee that will cover the communication costs, and that should be taken into consideration.

Similar to cell phones, these products use a GSM/GPRS module that is powered by, typically, a Li-ion battery.

To simplify the reading of the present day pet tracking systems, Table 1 draws a comparison of some of the more relevant ones.

Table 1- GSM/ GPRS network ranged trackers

Product	**Size**	**Battery life**	**Price**	**Month cost**	**Activation**
Tagg	For pets 4.5 kg and up	Average: 14-20 days Travel: 3-4 days	77 €	6 €	0 €
Loc8tor Pet GPS	Not for small breeds	4-10 days with typical use	290 €	12-40€	0 €
Lovemypets GPS	Not for small breeds	2 weeks on standby	175 €	12 €	15 €
SpotLite GPS	For pets 4.5 kg and up	5 days with typical use	115€	15 €	23 €
Retrieva	For pets 4.5 kg and up	5-10 days with typical use	300 €	8 €	0 €

From the listed products only Tagg, based on the United States, offers activity monitoring.

While the GSM based products are good for the everyday pet owner, hunters may take some advantages from the RF locators. These devices are more robust and responsive and are prepared for rough environments. These devices also allow tracking up to 15 dogs simultaneously.

These factors also originate a higher investment, although there is no need to pay monthly fees. The battery life is reduced as well as the range – as presented on Table 1

III. PROJECT DEVELOPMENT

A. Materials

In the process of developing our prototype we used several components which is shown in Table 2 below.

The materials chosen met all set criteria such as conditions such as price, weight, dimensions, assembling process and compatibility.

There was no support to perform surface mounting so the team decided to use breakout boards to simplify the process. This factor contributed for the price, weight and dimensions increase but simplified the assembling and the compatibility, excluding almost completely the use of extra hardware.

After comparing several products, the total price of the prototype, VAT included, is fixed at 279.55 EUR.

Table 2 List of materials

Product	**Description**
GPS	EM-408 with Antenna/MMCX
Arduino	Arduino Pro Mini 328 - 3.3V/8MHz
Battery	ENIX 3,7V 1840mAh
GPRS/GSM	ADH8066
GPRS/GSM Board	ADH8066 Breakout
Charger	LiPo Charger Basic - Mini-USB
Antenna(GSM)	GSMMQB - Mini Quad Band Antenna
Accelerometer	Triple Axis Accelerometer Breakout
Memory	I2C EEPROM - 1Mbit

B. Architecture and design

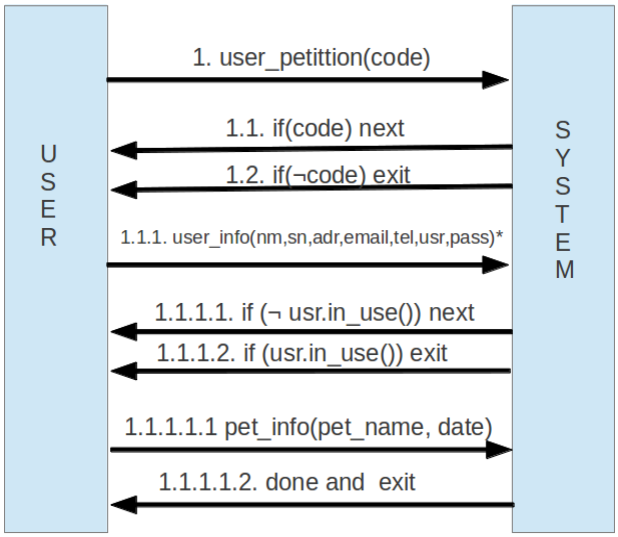
In project development it is very important to define how the product works. This system can be divided in several layers in order to be better understood.

1) Web Interface

Our product uses a web interface (Fig. 1, Fig. 2 & Fig. 3) to display all information that is sent from the Pet Tracker. There are several functionalities which our system is built upon.

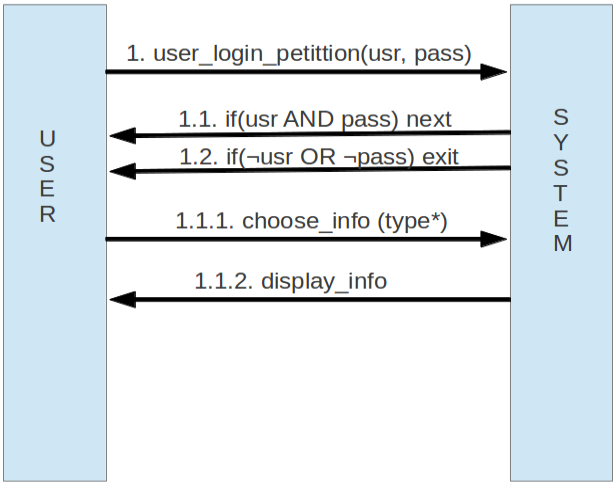
a) Use cases

Several processes are needed to ensure a satisfying experience on the website for the users. These are the most important use cases in our system:



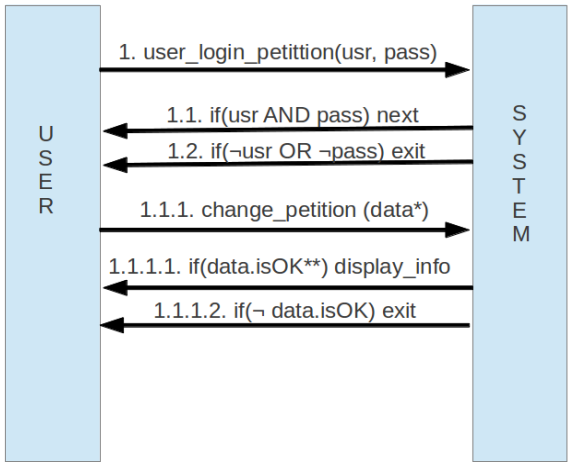
*
nm = name
sn= surname
adr= address
email= email
tel = telephone number
usr= user
pass = password

Fig. 1 - New user



*
type = General information / Activity information

Fig. 2 - Display pet's information



*
data = name OR surname OR address OR email OR tel

**
isOK() = checks if data format is correct

Fig. 3 - Edit user information

2) Control and acquisition

Fig. 4 presents the system's star architecture. The Arduino is the central structure that controls the other peripheral modules.

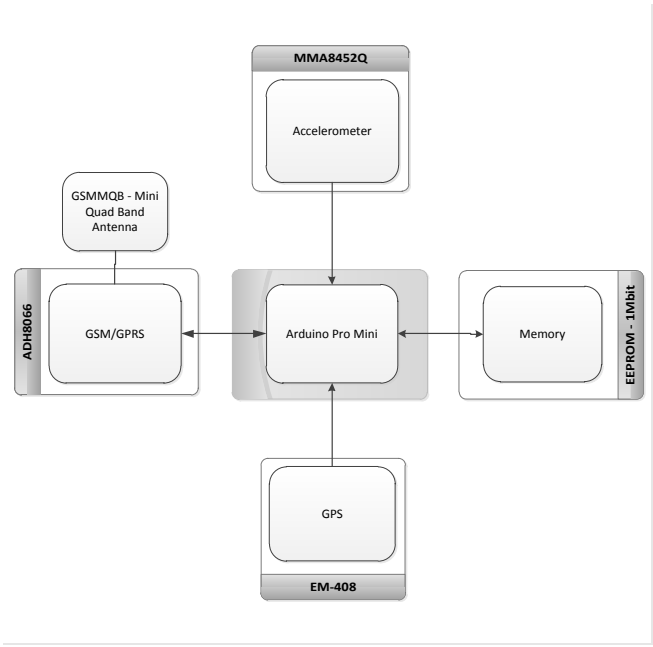


Fig. 4 System architecture

3) *Physical connections*

In order to ensure the correct power supply for all the components, it was necessary to regulate the power supplied by the battery from 3.75 V to 3.3 V. This is due to the operation voltage of the other modules. The power regulation is done by the MIC5205 power regulator built in the Arduino.

Since there is only one I2C bus available in the analog pins 4 (Serial Data Line) and 5 (Serial Clock), and both the accelerometer and the EEPROM need to access it, it was necessary to adapt and control the bus access. To avoid including more hardware to the device, i.e. an I2C multiplexer, it was decided to control the power supply for this modules using the digital pins 10 and 11. This way, both devices can share the I2C bus and use it only when requested. Fig. 5 illustrates the power distribution system.

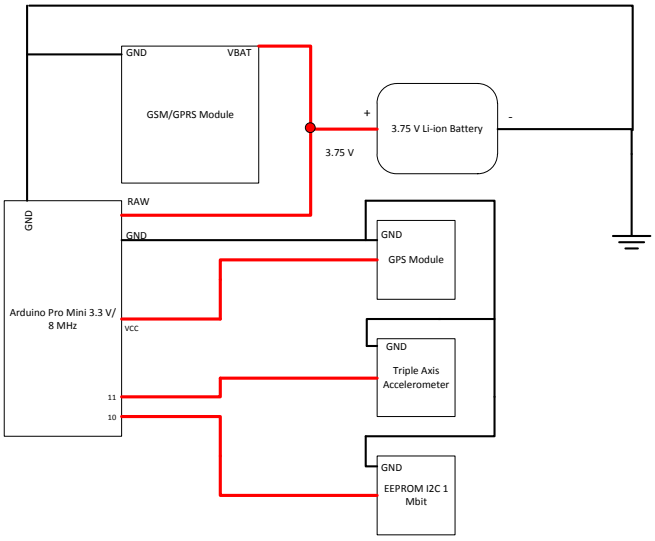


Fig. 5 - Power schematic

In order to control the device it was necessary to define the connections between the Arduino and the other modules.

Fig. 6 displays the connections made.

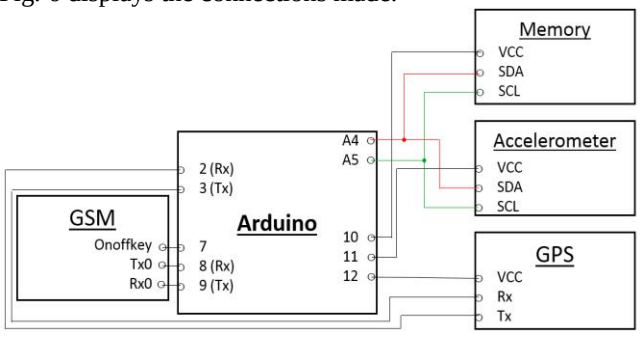


Fig. 6 - Control schematic

C. *Modules*

The pet tracker makes use of two fundamental modules, one used to communicate and one to locate with precision. These modules are the GSM/GPRS, the ADH8066 and the EM-408 GPS module.

1) *ADH8066*

This is a quad band GSM/GPRS communication module. It supports standard AT commands and enhanced AT commands which provide rich voice and data communication functions. It's an ideal solution for various communication applications [9]. With its dimensions at 33mm×36mm×5.4mm, and the weight of 8 g, this device will allow our pet tracker to communicate with the user and make it small and light enough to be used by the pet.

2) *EM-408*

This engine board is low cost but maintains high reliability and accuracy making it an ideal choice for integration with OEM/ODM (Original Equipment Manufacturer/ original design manufacturer) systems. The EM-408 features an integrated patch antenna for complete implementation [10]. This module will allow locating the pet with precision.

3) *MMA8452Q*

This is a small, low-power triple-axis breakout board with 12 bits of resolution, programmable output data rates and user selectable full scales of ±2 g/±4 g/±8 g [11]. It communicates using the Inter-Integrated Circuit (I2C) bus. It will be the device responsible for monitoring the pet's activity.

D. *Tests*

1) *Mechanical and electrical*

The following tests must be done:

- Track the product (Standard state)
- Check Secure Area functionality
- Check accuracy in meters
- Track the product in different situations:
  - Rain (water)
  - Cold (+, ~0 , -)
- Check battery charging system
- Check battery power autonomy

2) *Software*

Tests to perform:

- Create new user (Using standard user account)
- Create new user (Using master account)
- Register new pet (Using standard user account)
- Register new pet (Using master account)
- Edit user information (Using standard user account)
- Edit user information (Using master account)
- Edit pet information (Using standard user account)
- Edit pet information (Using standard user account)
- Remove user (Using standard user account)
- Remove user (Using master account)
- Remove pet (Using standard user account)
- Remove pet (Using master account)

E. Future developments

With due time, money and infrastructures we would like to further develop this product. In the future our device should become smaller, lighter, more accurate, more elegantly designed and more power efficient. The website should become more stylish, responsive and include more options and functionalities.

1) Device

The current device is only suitable for large pets, and the purpose of such product is to be small and light enough to fit a small dog or a cat.

We could achieve such product using surface mount devices and therefore excluding the evaluation and breakout boards used in the prototype. The Pet Tracker 2.0 should use, as an example, the fallowing components:

- A single chip microcontroller, e.g. ATxmega128A4-AU [12].
- A surface mount GPS module, e.g. PA6H by GlobalTop Technology Inc. [13].
- A surface mount accelerometer, e.g. LIS331DL [14].
- A surface mount GSM module with embedded SIM card, e.g. SL6088 [15].

The device would become smaller, more efficient and with a lower power consumption. A water proof ABS polymer shell should protect the equipment. This type of polymer, used in the automotive industry, is very resistant and durable and easily moulded using plastic moulding technologies.

2) Website

Future developments regarding the website should include:

More than one pet per user – There will be a possibility to monitor and track more than one pet per account. This feature will improve everyday use experience and simplify the system administration. This way, administrators will have a more centralized information system.

Complex activity statistics – Final customers will be able to see more statistics and graphs about the pet's activity, therefore getting more detailed information.

IV. Conclusion

From the very beginning, we tried to organize our work and divide the different tasks among members of our team. Considering the schedule and deadlines, we did our best to fulfil all the objectives and create a real life working device. Unfortunately, some unpredictable circumstances appeared and we were not able to receive the components con time. Even though, we tried to make progress with the other parts of the project such as the report, paper, poster, website, programming (the components we were waiting for) and video.

When we finally got the materials, three days away from deadline, the Pet Tracker's prototype assembly became real. We then needed to execute the planned process: test the modules individually, assemble everything together, and test the device as a unit. We did not have enough time to thoroughly test the product and obtain enough results for deeper analysis.

During the whole semester we tried to make the best decisions and choices, taking into consideration both requirements from our client and supervisors. We were proactive, adapted to new circumstances and were able to understand the true meaning of teamwork.

We are sure that this experience - working in the international team, gave us a huge opportunity to expand our knowledge and improve our soft skills, which will be very useful for our life as engineers.

V. Acknowledgment

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References

[1] "Single-board microcontroller - Wikipedia, the free encyclopedia." [Online]. Available: http://en.wikipedia.org/wiki/Single-board_microcontroller. [Accessed: 08-Apr-2013].

[2] "Arduino - ArduinoBoardProMini." [Online]. Available: http://arduino.cc/en/Main/ArduinoBoardProMini. [Accessed: 10-Apr-2013].

[3] "Wireless - Wikipedia, the free encyclopedia." [Online]. Available: http://en.wikipedia.org/wiki/Wireless. [Accessed: 11-Apr-2013].

[4] "GSM - Wikipedia, the free encyclopedia." [Online]. Available: http://en.wikipedia.org/wiki/GSM. [Accessed: 11-Apr-2013].

[5] "General Packet Radio Service - Wikipedia, the free encyclopedia." [Online]. Available: http://en.wikipedia.org/wiki/General_Packet_Radio_Service. [Accessed: 11-Apr-2013].

[6] "Satellite navigation - Wikipedia, the free encyclopedia." [Online]. Available: http://en.wikipedia.org/wiki/Satellite_navigation. [Accessed: 05-Apr-2013].

[7] "Battery (electricity)," *Wikipedia, the free encyclopedia*. 05-Mar-2013.

[8] "Advantages & Limitations of the Lithium-ion Battery - Battery University." [Online]. Available: http://batteryuniversity.com/learn/article/is_lithium_ion_the_ideal_battery. [Accessed: 12-Mar-2013].

[9] "ADH8066 GSM Module - SparkFun Electronics." [Online]. Available:

https://www.sparkfun.com/products/10138. [Accessed: 14-Apr-2013].
[10] "20 Channel EM-408 SiRF III Receiver with Antenna/MMCX - SparkFun Electronics." [Online]. Available: https://www.sparkfun.com/products/8234. [Accessed: 14-Apr-2013].
[11] "Triple Axis Accelerometer Breakout - MMA8452Q - SparkFun Electronics." [Online]. Available: https://www.sparkfun.com/products/10955. [Accessed: 12-Apr-2013].
[12] "Compre Microcontroladores 8 bit Microcontroller, AVR XMEGA, 32KB Atmel ATXMEGA32A4-AU na RS Online e o receberá em 24/48 horas." [Online]. Available: http://pt.rs-online.com/web/p/microcontroladores/6963102/?searchTerm=ATXMEGA32A4-AU&relevancy-data=636F3D3226696E3D4931384E4B6E6F776E41734D504E266C753D7074266D6D3D6D61746368616C6C7061727469616C26706D3D5E5B5C772D5C2E2F252C5D2B2426706F3D313326736E3D592673743D4D414E5F504152545F4E554D424552267573743D4154584D454741333241342D41552677633D424F544826. [Accessed: 20-May-2013].
[13] "G.top PA6H Low Profile High Sensitivity GPS Module with Integrated Patch Antenna." [Online]. Available: http://www.alphamicro.net/us/franchises/globaltop-technology/pa6h.aspx. [Accessed: 20-May-2013].
[14] "Compre Circuitos Integrados de Acelerómetro Accelerometer Triple +/-2g/8g 2.5V LGA16 STMicroelectronics LIS331DL na RS Online e o receberá em 24/48 horas." [Online]. Available: http://pt.rs-online.com/web/p/circuitos-integrados-de-acelerometro/7147901P/. [Accessed: 20-May-2013].
[15] "Sierra Wireless - AirPrime SL Series 2G/3G wireless modules." [Online]. Available: http://www.sierrawireless.com/en/productsandservices/AirPrime_Wireless_Modules/Smart_Modules/SL_Series.aspx. [Accessed: 20-May-2013].