# Chapter 2

# Station Hardware

In this section we want to describe in an exhaustive way hardware components present in our station. We are going to show model chosen compared to existing, their features and why we chose them for our system.

## 2.1 Touchscreens

### 2.1.1 Introduction

A touchscreen is a display that can detect the presence and location of a touch within display area. The term generally refers to touch or contact to the display of the device by a finger or hand. The use of touchscreens has soared in recent times. Is possible to find these systems in many different areas, like the business area (cash registers in many pubs and bars use these systems to record orders) or even in daily use with new generation cellular phones (for example Iphone 3G, Figure 2.1) Their main advantage is that are input and output data devices in a single device, in this way space is optimized and they gave a more intuitive and agile use.

Touchscreens were born in 1971 by the hand of Sum Hurst, Elograph sensor creator, however until 1974 was not created the fist transparent screen that allowed us to see that we pressed and closer to touchscreens we know now.

### 2.1.2 Touchscreens technologies

There are a number of types touchscreen technologies, more popular ones are: resistive system, surface acoustic wave and capacitive [3].

Figure 2.1: Iphone 3G

The **resistive system** consists of a normal glass panel that is covered with a conductive and a resistive metallic layer (like we can see in the next figure). These two layers are held apart by spacers, and a scratch-resistant layer is placed on top of the whole setup. An electrical current runs through the two layers while the monitor is operational. When a user touches the screen, the two layers make contact in that exact spot. The change in the electrical field is noted and the coordinates of the point of contact are calculated by the computer. Once the coordinates are known, a special driver translates the touch into something that the operating system can understand, much as a computer mouse driver translates a mouse's movements into a click or a drag (see Figure 2.2).

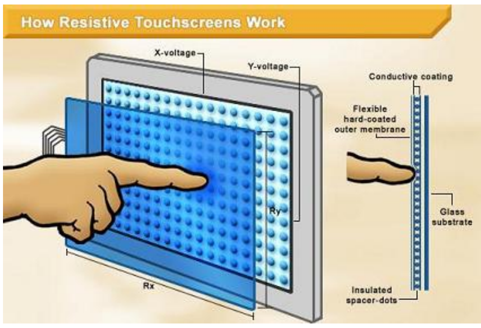


Figure 2.2: Resistive touchscreen structure

In the **capacitive system**, a layer that stores electrical charge is placed on the glass panel of the monitor. When a user touches the monitor with his or her finger, some of the charge is transferred to the user, so the charge on the capacitive layer decreases. This decrease is measured in circuits located at each corner of the monitor. The computer calculates, from the relative differences in charge at each corner, exactly where the touch event took place and then relays that information to the touch-screen driver software (Figure 2.3).

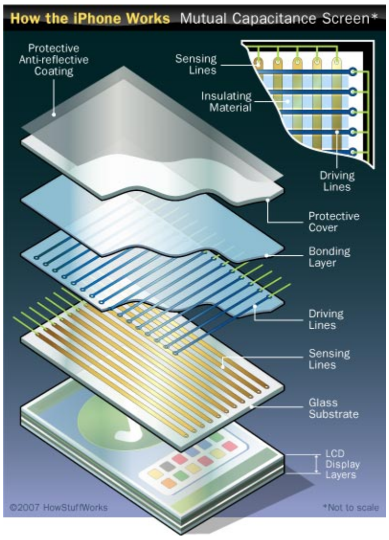


Figure 2.3: Capacitive touchscreen structure

One advantage that the capacitive system has over the resistive system is that it transmits almost 90 percent of the light from the monitor, whereas the resistive system only transmits about 75 percent. This gives the capacitive system a much clearer picture than the resistive system.

There are many capacitive devices in the market, usually they are more expensive that resistive ones (due to the improvement in the sharpness of the image) However, resistive system are more resistant to chafing due to the protector layer that cover the entire system (this layer is the guilty of the lost in the sharpness in the resistive system)

On the monitor of a **surface acoustic wave system**, called SAW systems, two transducers (one receiving and one sending) are placed along the x and y axes of the monitor's glass plate. Also placed on the glass are reflectors (we can see that in Figure 2.4 below), they reflect an electrical signal sent from one transducer to the other. The receiving transducer is able to tell if the wave has been disturbed by a touch event at any instant, and can locate it accordingly. The wave setup has no metallic layers on the screen, allowing for 100-percent light throughput and perfect image clarity. This makes the surface acoustic wave system best for displaying detailed graphics (both other systems have significant degradation in clarity).

Another area in which the systems differ is in which stimuli will register as a touch event. A resistive system registers a touch as long as the two layers make contact, which means that it doesn't matter if you touch it with

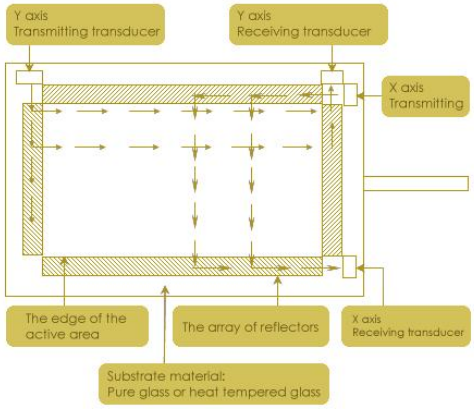


Figure 2.4: Schematic of a SAW system

your finger or a rubber ball. A capacitive system, on the other hand, must have a conductive input, usually your finger, in order to register a touch. The surface acoustic wave system works much like the resistive system, allowing a touch with almost any object except hard and small objects like a pen tip. As far as price, the resistive system is the cheapest; its clarity is the lowest of the three, and its layers can be damaged by sharp objects. The surface acoustic wave setup is usually the most expensive. Other less popular touchscreen technologies are those based in infrared with bands located horizontally and vertically to detect and triangular point where the broadcast is interrupted, and the pressure sensors. This last technology has the advantage that is the most resistant system, so is the best election to install in public places. It is based in four sensors, one in each corner of the screen which allow to determinate where the screen was pressed. Now we can see in the table below a comparative between different technologies in market. These dates have been extracted from a touchscreens dealer.

In the Figure 2.5, we can check all was said before. Resistive systems are the cheapest and are very resistant to external agents, but transparency and resolution are bad, these systems show a blurred image.

Until now, we have only taken into account systems which can detect one touch in each moment, commonly called One-touch systems. Recently a new type of touchscreen is being developed, these touchscreens are able to detect multiple touches simultaneously and have associated software that allows them to interpret this situation. They are the called Multi-touch screens. These screens consist of an array of optical sensors to obtain the position of some contact points at the top of the screen simultaneously.

**Comparison**

| | Contact media | Surface Material difference | Resist water/ dust performance | Transparency Resolution | Price |
|---|---|---|---|---|---|
| Gtouch 5 wire Resistive | Hand or any media | Enhance glass base ITO super hardness surface ,endure to abrasion & scratch | Excellent | 80%↑ 4096 × 4096↑ | Reasonable & beneficial |
| Gtouch Saw | Hand & soft media only | Whole set glass material | System response delay | 95% ↑ 1024 × 1024↑ | Normal |
| Gtouch Capacitive | Hand Only | Whole set glass material | Excellent | 95%↑ 4096 × 4096 | Expensive |
| Gtouch Infrared | Hand or any media | Whole set glass material | Little affect system performance | Glass 95%↑ 1000 × 720↑ | Normal |
| Electromagnetic | Special-purpose pen | Any media on a regular basis. | Affect system performance | Glass 95%↑ 4096 × 4096 | Expensive |

Figure 2.5: Comparison of touchscreen technologies

Often is possible to measure the pressure and the angle of any contact point independently too, which allow makes gestures or interact with several fingers or hands simultaneously and provides a rich and varied interaction through more intuitive gestures. Moreover, these systems allow several users at the same time and make zooms in the application they are using only with their fingers, more easy and direct way than if we would use the mouse. An example of this type of touchscreens is the "Surface" from Microsoft (Figure 2.6):

Last screens (Multi-touch screens) are very new for this project, but I think they will be important in the future. When technology will be cheaper

Figure 2.6: MicrosoftSurface

and applications will be more developed is possible to use this screens to improve performance in our station, because the fact we can detect more than one touch simultaneously increases our possibilities and provides a more agile and efficient use than conventional touchscreens.

### 2.1.3 Touchscreens of the station

Boeing gives us the following models of touchscreen:

- 19" screen IntelliTouch surface wave technology (USB interface)
- 19" screen Accutouch 5-wire resistive technology (USB interface)
- 17" screen IntelliTouch surface wave technology (USB and RS232 interfaces)
- 17" screen Accutouch 5-wire resistive technology (USB and RS232 interfaces)

The aim was to compare the two technologies and see the advantages of each one. If we take into account the table shown in the Figure 2.5 (comparison of touchscreen technologies), and supported by the practical use, we can say that SAW technology is far superior to the resistive technology, better response and a more sharpness image. We need to discuss pro-resistive systems which we said before about its resistance, this system type is very

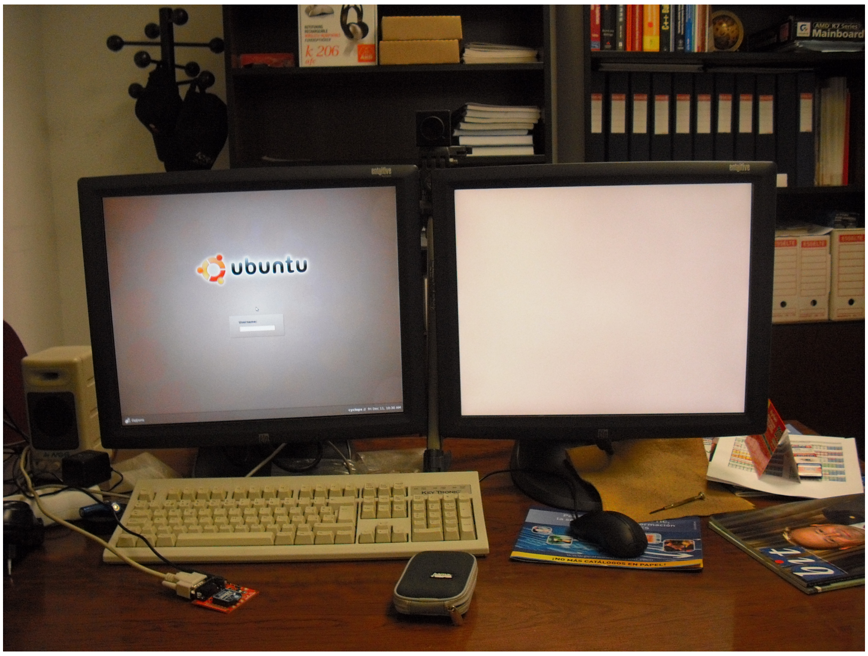


Figure 2.7: Touchscreens System

resistant to abrasion and scratching. The resulting system can be seen in the image above (Figure 2.7).

## 2.2 Fireware camera

We want to use in our Multimodal display the tool called Head-Tracking (this tool will be seen with more detail in the section on software tools), with a camera, we can detect usert́s head and we can detect movements of the usert́s head. This can be very useful if we take into account that in our station there are three screens and with Head-Tracking we can know where operator are looking all the time, which allows to improve for example system alarms (we could show triggered alarm on the monitor that operator is looking at the moment which is appeared). A conventional webcam (like is showed in Figure 2.8 below) is sufficient to implement Head-Tracking if it is supported by image recognition software.

Figure 2.8: Conventional webcam

These devices have become especially popular among people who use instant messaging programs such as Microsoft's Messenger. In fact they have become so popular that most laptops are brought integrated in the market. But commercial devices have many problems, system response depends on the lighting conditions, so different lighting conditions produce different system response.

We need a robust system with an answer as accurate as possible regardless of the conditions. For that reason the final choice was a camera that can detect infrared light, in that way we can reduce the negative effects of the visible light in our system. But now, we need an infrared pattern to be able to implement the Head Tracking, the solution to this problem was very simple, was decided to use a pattern of infrared LEDs located on the UAVs operator headphones. Just like that we can detect operator head movements thanks to the position of the LEDs in him headphones. The pattern consist of 4 infrared LEDs located two in each side of the headphones (like we can see in the figureĚ. later). But despite our efforts system had some drift in the calculation of the yaw (angle equivalent to looking to the right or left), due this was decided to include the Atomic IMU -6DOF- Xbee Ready to mount the Head Tracking System. Together, the atomic IMU, Fireware cam and headphones with the infrared LEDs pattern will compose a robust and accurate Head Tracking system.

The chosen camera model was a Fireware camera model DMK-21F04 from "The imaging source" (as we can see in the picture below).


Figure 2.9: Camera DMK-21F04

Its general specifications are the next:

**General behavior:**

- Video formats @ Frame rate 640 x 480 Y800 @ 30, 15, 7.5, 3.75 fps
- Sensitivity 4 lx at 1/30s, gain 0 dB
- Gamma 0.45, 1
- Dynamic range ADC: 10 bit, output: 8 bit
- SNR ADC: 9 at 25 řC, gain 0 dB

**Interface (optical):**

- Sensor specification ICX098BL
- Type progressive scan
- Format 1/4 "
- Resolution H: 640, V: 480
- Pixel size H: 5.6 ţm, V: 5.6 ţm
- Lens mount C/CS-mount

**Interface (electrical):**

- Supply voltage 8 to 30 VDC

- Current consumption approx 90 mA at 12 VDC

**Adjustments (man):**

- Shutter 1/3300 to 1/30 s
- Gain 0 to 36 dB
- Offset 0 to 511
- Sharpness 0 to 255
- Gamma 0.451

**Adjustments (auto):**

- Shutter 1/3300 to 1/30 s
- Gain 0 to 36 dB
- Offset 0 to 511

**Environmental:**

- Max. temperature (operation) -5 řC to 45 řC
- Max. temperature (storage) -20 řC to 60 řC
- Max. humidity (operation) 80
- Max. humidity (storage) 95

Firewire cameras allow modify several parameters related with the image capture. In our case, we are interested in three parameters to have a more realistic image, so gain and brightness are set to zero, but we want the camera to automatically adjust to changes in illumination, so the autoexposure is activated.

A very important aspect into the camera parameters is the sensitivity of the sensor used. The sensor must be able to perceive as much as possible into the near infrared in order to detect the emission of the LEDs. The sensitivity of the sensor mounted in the camera is shown in Figure 2.10. It can be seen how the sensitivity is maximum around 510nm (green colors) and how the sensitivity around the 810nm (our infrared LEDs) is about 30

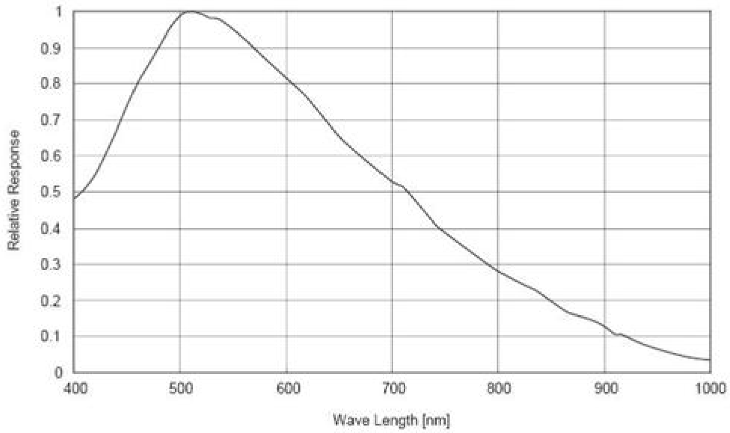


Figure 2.10: Sensitivity of the camera sensor

In the next section we will see the implementation of the infrared filter and how this filter eliminates the visible light and let us to take only the information given for the infrared LEDs.

## 2.3 Infrarred LEDs

Like we could see before, we have problems to get an accurate Head Tracking due to lighting conditions. Conventional Head Tracking works well, but when you change lighting conditions can generate not desired behaviors. For this reason was decided to introduce an infrared LEDs pattern located in the Headphones of the operator (see figure xx in the next section, Headphones). This pattern allows us know the operatorťs head position all the time and supported with the Atomic IMU-6DOF- detect its movements.

But, what is a LED? A **light-emitting diode (LED)** is an electronic light source [20]. LEDs are used as indicator lamps in many kinds of electronics and increasingly for lighting. LEDs work by the effect of electroluminescence, discovered by accident in 1907. The LED was introduced as a practical electronic component in 1962. All early devices emitted low-intensity red light, but modern LEDs are available across the visible, ultraviolet and infra red wavelengths (this last type is the interesting for us), with very high brightness.

LEDs are based on the semiconductor diode. When the diode is forward biased (switched on), electrons are able to recombine with holes and energy is released in the form of light. This effect is called electroluminescence and the color of the light is determined by the energy gap of the semiconductor. The LED is usually small in area (less than 1 mm2) with integrated optical components to shape its radiation pattern and assist in reflection.

LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, faster switching, durable and reliable. However, they are relatively expensive and require more precise current and heat management than traditional light sources. Current LED products for general lighting have higher costs than fluorescent lamp sources of comparable output.

Applications of LEDs are diverse. They are used as low-energy indicators but also for replacements for traditional light sources in general lighting, automotive lighting and traffic signals. The compact size of LEDs has allowed new text and video displays and sensors to be developed, while their high switching rates are useful in advanced communications technology.

With the aim to detect the position of operatorťs head, was decided to use four infrared LEDs, also called IRED (Infra-Red Emitting diode). Using infrared LEDs to build the pattern to be detected by the head tracking software has two main advantages. First, the infrared LEDs are not visible by the human eye. This is very important because guarantees that the visual information will not interfere with the operators tasks. This is shown in Figure 2.11, where the spectrum of the emission of an infrared LED centered in 810nm is compared with the wavelength of the different colors perceived by humans.

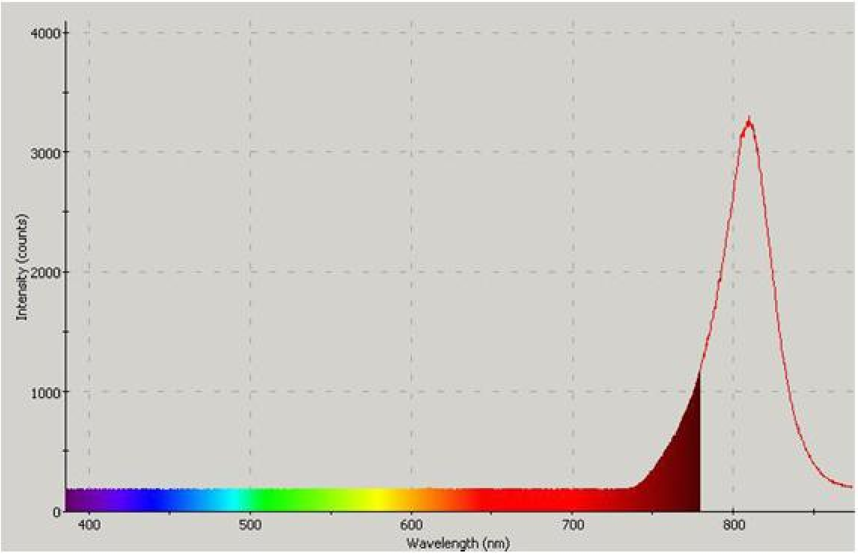


Figure 2.11: Visual and near infrared spectrum

Figure 2.12: Blue infrared LED

Different alternatives were shuffling, and finally was decided to use blue infrared LEDs (shown above in figure 2.12), these LEDs are more appropriate to this task that white ones, due to white ones are more directive and have a great power if the user looks straight at the camera, but loses much light as we turn the head sideways or up and down. On the contrary, blue infrared LEDs do not have as much power like white ones but this let them to give an acceptable power level despite the gyrations of the head. This quality makes blue infrared LEDs the best choice in our station and gives us a very robust system and a very good light signal regardless of the operatorś head position.

To build the pattern was needed to feed the LEDs and placing an adaptation resistance. Was decided to use the power of the headphones, 2.71V, in that way was possible an energy saving of Lipo (the battery used to power the IMU which will be composed in the headphones as discussed in future sections). Like IREDs chosen needsĚ we locate two LEDs and the resistance in the right side and left side of the headphones. The resulting electronic scheme shown in the following figure (one in each side):

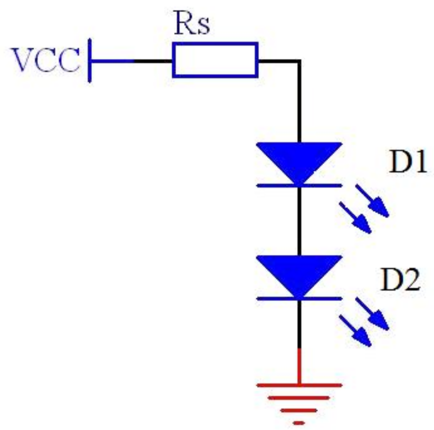


Figure 2.13: Electronic Scheme for infrared LEDs

### 2.3.1 Infrared filter

It is necessary to design the filter to cut down the information gathered by the camera, focusing into the infrared information. This filter is attached to the optic of the camera, removing all the information out of the selected band. The following constraints have to be taken into account:

- The filter must have as much transparency as possible around 810nm.

- The filter must reject any visual component below 770nm.

Under these constraints, the filter 093 provided by The Imaging Source company has been selected. The transparency of the filter can be seen in Figure 2.14. It is shown how the transparency at 810nm is approximately 30% and how it rejects all the components below 750nm. Finally, Fig. 2.15 presents the joint response of the complete system: infrared emission, filter and camera sensor. It is shown how the camera sensor will reject all visual components, focusing in the near-infrared emission of the LEDs. It is also shown that although there is a significant attenuation of the LEDs emission due to filter and sensor sensitivity, it is compensated with higher infrared emission.

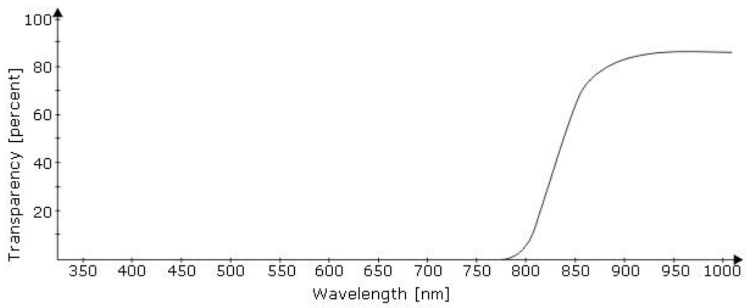


Figure 2.14: Transparency of the infrared filter

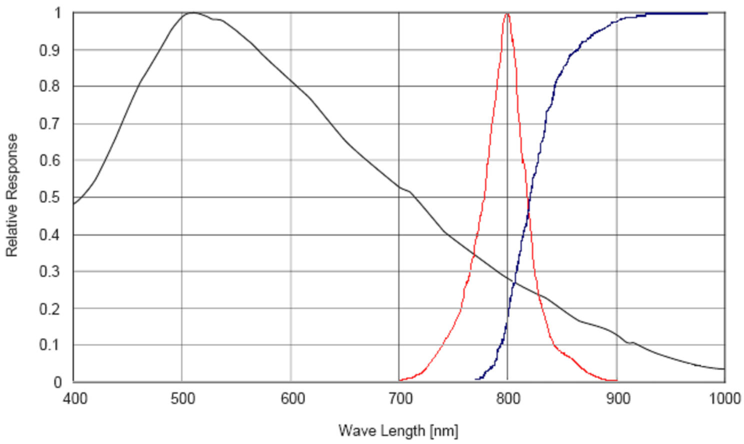


Figure 2.15: Joint response of the overall system: camera sensor (black), infrared emission (red) and filter transparency (blue)

## 2.4 Atomic IMU -6 DOF- XBee Ready

The first attempt to carry out the Head-Tracking had only the pattern of LEDs and the camera Fireware, but in practice were observed drifts in the calculation of yaw (the equivalent angle to looking left and right). This error was cumulative and induced to very large errors after prolonged use of Head-Tracking. For this reason it was decided to include a new hardware element to correct this error and in addition to improve system response. The chosen element was the 6DOF Atomic IMU, which is composed with three gyroscopes and an accelerometer and thanks to XBee system (a wireless communication system) we can integrate the IMU in the headphones (see the next section) in order to obtain a more accurate Head-Tracking System.

The 6DOF (Degree Of Freedom) Atomic is a stripped-down IMU unit, designed to give good performance at a low price. The unit can run as a hard-wired UART interface (0-3.3V, 115200bps), or optionally with an XBee TM RF module, and is powered from a single LiPo (Lithium Polymer) cell.

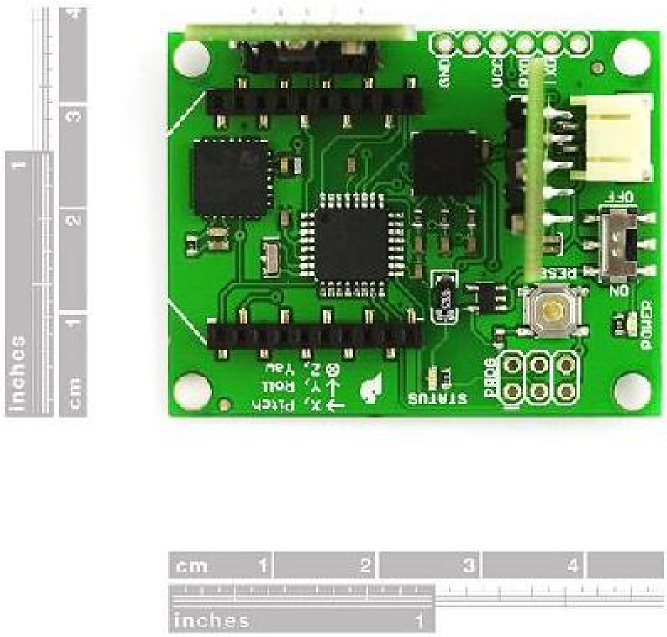


Figure 2.16: 6DOF Atomic IMU

The processor is an Atmel ATMega168TM running at 10MHz with 6 dedicated 10-bit ADC channels reading the sensors. Source code for the 6DOF Atomic is freely available and compiles with the free AVR GCC compiler.

The 6-DOF Atomic uses these sensors:

- Freescale MMA7260Q TM triple-axis accelerometer, settable to 1.5g, 2g, 4g or 6g sensitivity

- 3 ST Microelectronics LISY300AL TM singleaxis, 300ř/s gyros

**Electrical Specifications:**

- Input voltage: 3.4V to 10V DC
- Current consumption: 24mA (75mA with XBee)
- Sensor bandwidth and resolution:
- LISY300AL Gyros: 88Hz, 0.977ř/tick (ADC count)
- MMA7260Q Accelerometer:
- 350Hz, X and Y axes
- 150Hz, Z axis
- 0.00403g/tick @ 1.5g
- 0.00537g/tick @ 2g
- 0.0107g/tick @ 4g
- 0.0161g/tick @ 6g

The MMA7260Q accelerometer and the LISY300AL gyros have each been set up per their manufacturer's recommendations, i.e. internal clock suppression filters on their outputs.

These sensors are also internally temperature compensated. For a full description of the sensor specifications, please see the respective manufacturer's data sheets [18].

Figure 2.17 illustrates an overview of all the hardware that composes the integrated circuit.

The numbers which we can see in the last figure are:

1. Power indicator LED
2. Reset switch for the ATMega168
3. Power Switch
4. JST power connector for single Lipo cell
5. Serial port, 0-3.3V, 115200/8/1/N. The unit can optionally be powered with 3.4V to 10Vfrom this port by closing the solder jumper marked "9" in Figure 2.18.
6. Programming port for ATMega168

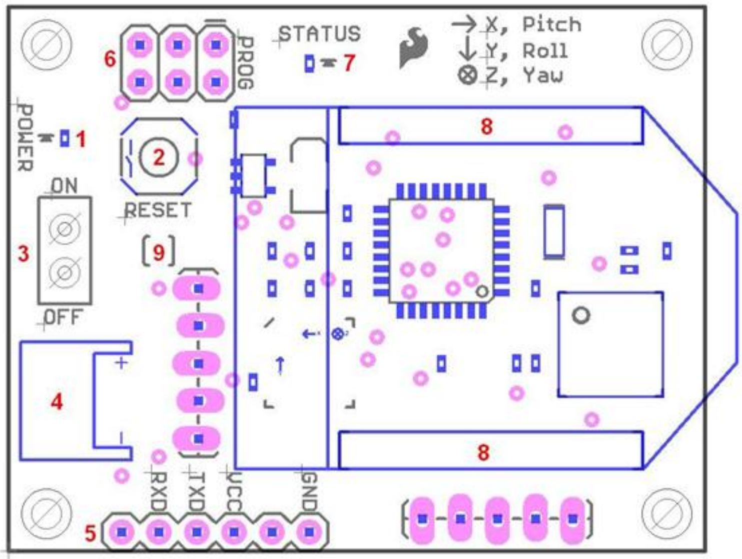


Figure 2.17: Hardware overview

7. Status LED, blinks at the sample rate when unit is sampling, off otherwise

8. Sockets for optional XBee RF module

9. Solder jumper, connects VCC on the serial port to the battery input

As noted earlier, the Atomic 6DOF can function as a device connected by cable or optionally with a pair of XBee modules RF (radio frequency). The measure used in both cases is the same, the UART built into the IMU, so it is not necessary firmware configuration to operate in both modes. However, be careful not to connect both modes simultaneously since it can create conflicts in the UART and potentially damage the unit. In our case we decided that the communication was by radio, availing XBee device, this decision follows the use to which it is intended to give the IMU at the station. The aim is to install the IMU into the operator ́s headphones in order to encourage and facilitate the Head-Tracking tool that is only detecting the head of the operator at all times. In the next chapter in the section on Head-Tracking shall see how the IMU helps us detect the movements of the head of the operator, and an introduction to the detection of movements using accelerometers and gyroscopes.

But, it was needed to connect the receiving XBee antenna with the station computer. With the aim to compute the data sent from Atomic IMU. Finally was decided to connect it through serial port. We can see it in the Figure 2.18.

Figure 2.18: XBee Explorer Serial

XBee Explorer Serial has the follow features: this is a simple to use, RS232 to serial base unit for the XBee line. This unit works with all XBee modules including the Series 1 and Series 2.5, standard and Pro version. Plug the unit into the XBee Explorer, attach a RS232 cable, and you will have direct access to the serial and programming pins on the XBee unit. The board also supports DTR communication so you can reprogram and configure the XBee unit.

For more information about 6 DOF Atomic IMU, see the data sheet in the next direction referencia a bibliografía.

## 2.5 Headphones

### 2.5.1 Introduction

It was necessary the introduction of headphones in our system to provide a warning system audio and voice messages as comfortable as possible. Headphones are an electronic device that are placed over the ears or hearing, and you can listen sounds. Moreover, the addition of the headphones gives us the possibility to improve Head-Tracking system (we located in them the LEDs pattern and the 6DOF IMU) and use a new software tool called 3D Sound. This last tool will allow us locate sounds in the 3D space creating in the operator the impression that the sounds come from a particular point in space and operator will can identify it. This tool will be seen with more detail in the following section (Software tools).

In addition all said before, we thought that a wireless system would be more useful due to the elimination of wires, thus providing greater freedom of movement to the operator. And the fact that headphones have a battery will allow us to feed our new elements (LEDs and 6DOF Atomic IMU), but finally it was only possible to feed LEDs pattern because the two batteries only provided 2.71V and, like we can see in the last section, 6DOF Atomic IMU needs 3.3V. Moreover, it was needed another feature of the headphones, they must be big due to the need to install inside them the 6DOF Atomic IMU.

Finally the chosen model was AKG k 206 AFC like we can see in the following figure:


Figure 2.19: AKG k 206 AFC Headphones

### 2.5.2 AKG k 206 AFC features

First of all we are going to see technical features of the headphones and after that we will see the installation of the new elements in the Headphones.

**General**

- **Product Type** Headphones - Radio
- **Additional Features** Auto power off, Rechargeable capability Headphones
- **Headphones Type** Headphones - Binaural
- **Headphones Form Factor** Ear-cup
- **Headphones Technology** Dynamic
- **Connectivity Technology** Wireless - Radio
- **Sound Output Mode** Stereo
- **Response Bandwidth** 18 - 22000 Hz
- **Sensitivity** 105 dB

**Remote Control**

- **Type** None

**Wireless Link**

- **Radio Frequency Range** 864MHz , 916MHz
- **Modulation Type** FM
- **Transmission Range** 330 ft

**Connections**

- **Connector Type** 1 x Audio line-in ( RCA phono x 2 ) , 1 x Audio line-in (Mini-phone stereo 3.5 mm )

**Miscellaneous**

- **Cables Included** Audio cable - 5 ft
- **Included Accessories** FM transmitter , 6.3 mm (1/4") stereo adapter

**Power**

- **Power Device** Power adapter - External

- **Battery** 2 x Headphone battery - AAA type - Rechargeable - Nickel metal hydride

Additionally we can find this review about its technical features in some online stores:

AKG once again lives up to the expectations of its regular listeners and fans. The K 206 AFC delivers a full, rich sound with velvety bass, clean mids, and an airy high end a mature sound that is much better than you would expect of analog wireless headphones. A PLL synthesized tuner ensures higher radio performance, even through walls and ceilings. An integrated autotuning function provides optimum reception at the push of a button. In addition, the K 206 AFC combines environmental friendliness with comfort. The supplied NiMH battery packs will power the headphones for 15 hours before you need to charge them, which is as easy as placing the headphones on the chic transmitter/charger. The battery packs live longer than comparable rechargeable batteries, are more efficient, and have no memory effect, so their environmental impact is very low. The headphones are a circumaural, semi-open design. Gimbal-suspended ear cups and a self-adjusting headband ensure perfect fit. The pleasantly soft ear pads made of skin-compatible, breathing velour are of course washable and replaceable.

### 2.5.3 Adding the LEDs pattern

In this point we had chosen headphones and was time to create a headphone prototype for our station taking in account all said before. First of all was to see where we could locate the IMU and the LEDs pattern. We opened right and left ear cup and we could see the next:

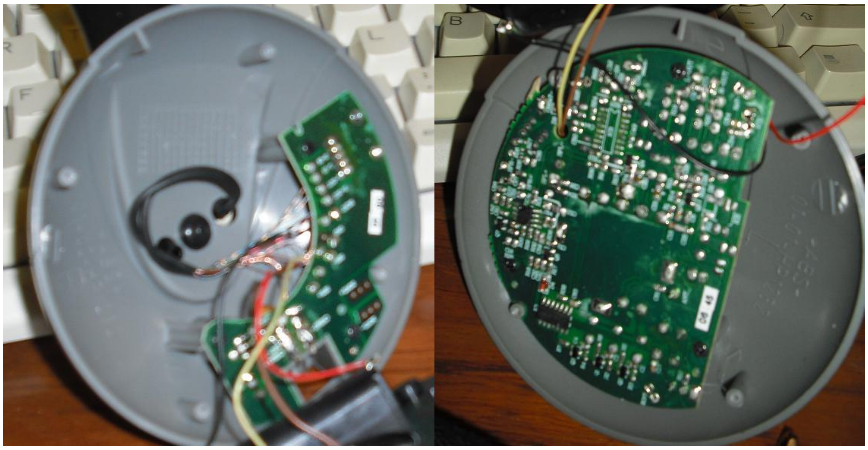

Figure 2.20: Right (to the left) and left (to the right) electronic of the Headphones

Like we can see the electronic of headphones allowed us to put inside right ear cup our 6DOF Atomic IMU, but due that we must to introduce the Lipo (to feed the IMU, because we need 3.3V and headphones batteries only give 2.71V), was necessary to make two holes in the right ear cup of the headphones to fit the two elements (Figure **??**). Note that this first prototype is not beautiful but we were looking for functionality, in future prototypes we will taking account this aspect and we will attempt to make a device to charge the Lipo without the need to open the top of the right atrial.

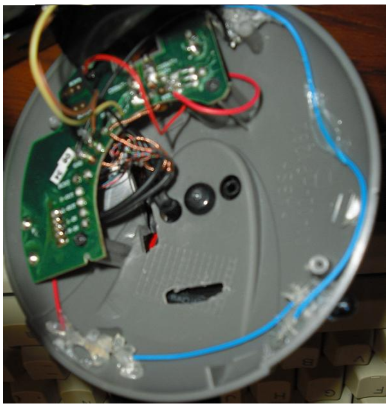

Figure 2.21: Holes for the IMU and LEDs circuit in right atrial

Once the IMU was located into the right atrial of our headphones, it was necessary to prepare the headset for the inclusion of the pattern of LEDs. This part was easier, because two LEDs and a resistance occupy very little space. Two holes were made in each atrial, each pair at about the same height. The connections are made internally to the headphones and only LEDs could be seen from the outside. In that way we got our aim none other than the light emitted by LEDs was captured by the Firewire camera.

Figure 2.22: LEDs circuit in the left atrial

Figure 2.23: Headphones of the station

To hold the LEDs and the resistance, it was used a hot silicone gun. When silicone cooled the circuit was set (Figures 2.21 and 2.22). It was necessary to solder wires to feed the LEDs with the battery of the headphones.

After placing The LEDs and the IMU, our headphones were ready to Head-Tracking. In addition to its inherent function (play sounds), we provided it with the ability to detect movements of the user's head. This new functionality will be seen with more detail in later sections. The final result can be seen in the Figure 2.23.

In the Figure 2.23, we can see that the IMU and the Lipo are located outside of the Headphones. This is due that we need to open the Headphones when the Lipo is discharged to charge it. For this reason, and only for the prototype (when the prototype was designed we neglected this potential problem) was decided to locate in this way the IMU and the battery. In futures headphones models we will try to solve this problem.

One of the advantages of this design was that we can still use the headphone base to charge it. While headphones not being used we can put them above their base and charge their batteries (see Figure 2.24), so we only have to worry about to charge the Lipo (battery that feed the IMU).

Another advantage of use these Headphones is in their base. Besides the inherent ability to charge the Headphones, the base can transmit sound in three different frequency bands, so we can have three different users in the same room with the same equip (that is to say with three different Headphones and bases each). All of them could receive speech instructions or oral warning without interferences between them.


Figure 2.24: Charging Headphones

## 2.6 Haptic devices (vibrators)

Another devices is present in the station are vibrators. These are haptic devices that allow us through vibration alert the operator of certain alarms that did not comply within a time limit and very important warnings, or even like we will see below (in applications section) to simulate situations such as the turbulence of the UAV.

Haptic technology is very fashionable, this technology is used in many different areas, like teleoperators and simulators, computer and video games, haptics in virtual reality, research, medicineĚ We can see that haptic technology "does for the sense of touch what computer graphics does for vision". This technology interfaces to the user via the sense of touch by applying forces, vibrations, and/or motions to the user. This mechanical stimulation may be used to assist in the creation of virtual objects (objects existing only in a computer simulation), for control of such virtual objects, and to enhance the remote control of machines and devices (teleoperators). This emerging technology promises to have wide-reaching applications as it already has in some fields. For example, haptic technology has made it possible to investigate in detail how the human sense of touch works by allowing the creation of carefully controlled haptic virtual objects. These objects are used to systematically probe human haptic capabilities, which would otherwise be difficult to achieve. These new research tools contribute to our understanding of how touch and its underlying brain functions work. Although haptic devices are capable of measuring bulk or reactive forces that are applied by the user, it should not be confused with touch or tactile sensors that measure the pressure or force exerted by the user to the interface.

Station vibrators were made by a colleague from the university and the board and its components are shown below:

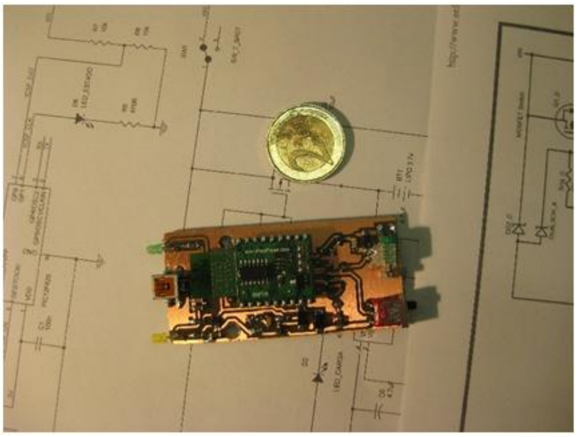

Figure 2.25: Board of vibrator

Taking in account all said before was built two prototypes with the aim to locate them in each arm of the operator. Tests were performed with a very good result. Now we are going to see the main features and functions if the created prototypes:

**Functions:**

- Selectable vibration: mode ON, mode OFF and mode PULSE.
- State LED which inform us about the state of the batteries, blinking at 2 or 4 Hz depending of batteries status (low or critic).
- Internal switch to take supply voltage through USB when mini USB wire was connected to the port.
- Charger for Lipo (Lithium polymer) on board.
- The devices can send the state of its batteries via Bluetooth.
- Compliant Bluetooth 2.0 device and USB compliant.
- Updatable Firmware.

**Features:**

- Consumption:
  1. Standby (Motor OFF + Radio OFF) = 10mA
  2. Motor ON + Radio OFF = 80mA
  3. Motor OFF + Radio ON = 150mA
  4. Motor USB $<$ 400mA (charge intensity of the LIPO 250 mA)
- Autonomy:
  1. Standby Mode $>=$ 24h
  2. Motor ON $>=$ 3h (Radio module transmit in periodic burst)
- Charge time $>$ 2h
- Battery: Lithium Polymer 320mAH
- Dimensions: 77x38x22mm
- Weight: 45gr

Finally, in Figure 2.26 we can see the price of each component and the final price of the prototype:

| Item | Quantity | Reference | Part | U. Cost | T. Cost |
|---|---|---|---|---|---|
| 1 | 1 | BT1 | LIPO 3.7v | 22,580 € | 22,580 € |
| 2 | 2 | C1,C3 | 100n | 0,049 € | 0,098 € |
| 3 | 2 | C2,C9 | 10uF | 0,066 € | 0,132 € |
| 4 | 3 | C4,C5,C8 | 0.1uF | 0,049 € | 0,147 € |
| 5 | 2 | C6,C7 | 4.7uF | 0,066 € | 0,132 € |
| 6 | 1 | D2 | LED_CARGA | 0,090 € | 0,090 € |
| 7 | 3 | D3,D4,D5 | SCHOTT | 0,232 € | 0,696 € |
| 8 | 1 | D6 | LED_ESTADO | 0,090 € | 0,090 € |
| 9 | 1 | D7 | 1n4148 | 0,028 € | 0,028 € |
| 10 | 1 | J2 | linkMatik2 | 105,620 € | 105,620 € |
| 11 | 1 | J3 | MOTOR | 10,000 € | 10,000 € |
| 12 | 1 | J4 | CON_MINI_USB | 0,820 € | 0,820 € |
| 13 | 1 | J5 | ICSP conn. | 0,200 € | 0,200 € |
| 14 | 1 | L1 | 10uH | 1,260 € | 1,260 € |
| 15 | 1 | Q6 | irlml6401 | 0,288 € | 0,288 € |
| 16 | 1 | Q7 | IRLML2502 | 0,710 € | 0,710 € |
| 17 | 4 | R1,R5,R7,R8 | 10k | 0,038 € | 0,152 € |
| 18 | 1 | R2 | 2k2 | 0,037 € | 0,037 € |
| 19 | 1 | R3 | 3.9k | 0,045 € | 0,045 € |
| 20 | 2 | R4,R6 | 470R | 0,032 € | 0,064 € |
| 21 | 1 | SW1 | SW_T_SPDT | 4,970 € | 4,970 € |
| 22 | 1 | U1 | PIC12F629 | 0,766 € | 0,766 € |
| 23 | 1 | U3 | MCP73831 | 0,932 € | 0,932 € |
| 24 | 1 | U4 | LP2980_3v | 0,764 € | 0,764 € |
| 25 | 1 | Case | External case | 2,350 € | 2,350 € |
| | | | | Total | 152,971 € |

Figure 2.26: Prize table of vibratos components

**Electronic scheme:**

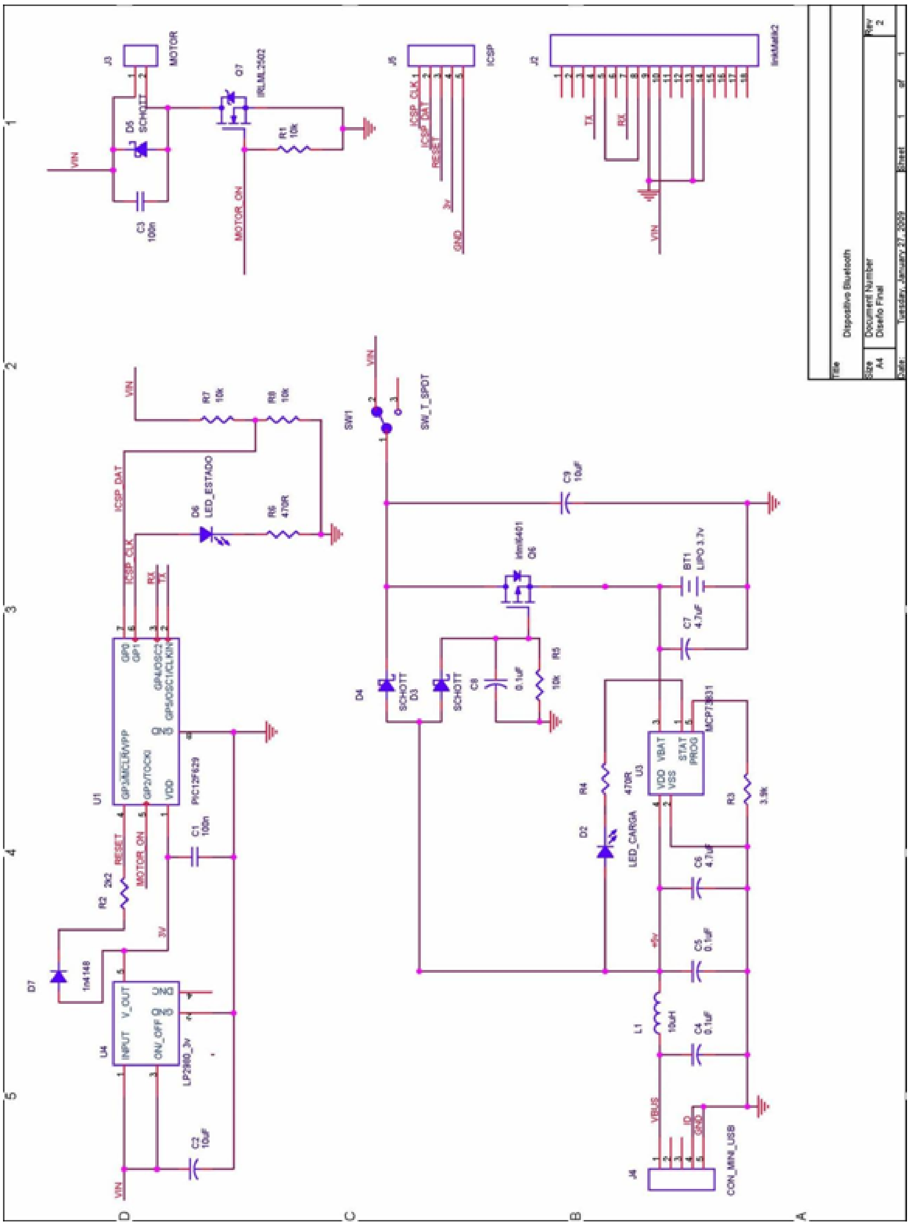

Figure 2.27: Electronic scheme of vibrator device

**PCB:**

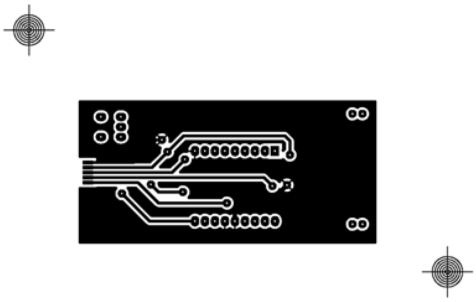

Figure 2.28: PCB underside

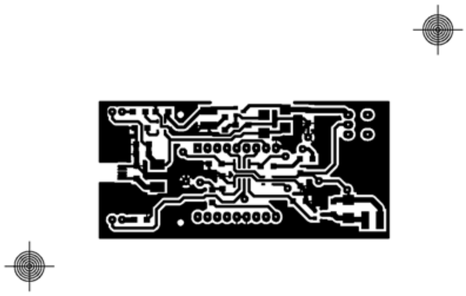

Figure 2.29: PCB upper face