Design of seismic acquisition system for volcanology

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Abstract- This paper presents a new design based on acquisition system of the volcanic seismic data. Mainly, this system is composed of a microcontroller to manage the peripherals, a module to acquire the information of seismic sensor and a module of communications that contains the RF and GPS system. The prototype aims to be a very low power system allowing also working during a complete year.

I. Introduction

Earthquakes, tsunamis and volcanic activity are some of the natural hazards studied by the experts and that still studied nowadays [1]. These natural phenomena are considered inevitable due to its natural origin and its large scale. However, these can be predicted thanks to the wide range of projects and methods developed by scientists. As a result the predictions are becoming more efficient and further provides better information on the structure and behaviour of Earth's mantle [2].

The main focus presented on this paper is a development of a system for monitoring volcanic activity [3] capable of capturing seismic data, save them in an internal memory and send them to a remote node. This equipment should satisfy the next requirements: minimize the environmental impact and vandalism, to have a low cost of implementation and maintenance, and to have a reduced volume and weight to facilitate installation but with a long autonomy. Based on these specifications, we have the following design requirements:

- Low cost.
- Low power (to work in a period of up to one year).
- Telemetry short range, up to 2 km.
- Data storage for 100 samples per second (Sps) and 24 bits.
- A lightweight and compact system.

Due to the installation of the equipments in remote and unprotected areas, becomes easy to thieves stealing, destroying, stealing or breaking the devices. Vandalism is one of the risks to which they must submit a remote and autonomous acquisition system. To avoid this problem as good as possible, or at least reduce the possibilities of being found, we will design a small and compact equipment enclosed it in a waterproof box where only small antennas will come out. In the final installation, the operator should bury the device which contains the electronics inside him, leaving only the antennas visible. Regarding the electronic design, the most restrictive requirement is the correct calculation of power consumption for each component and also to choice the proper battery to work until a year using a low system weight.

II. Acquisition system structure

The proposed acquisition system is represented in the block diagram of figure 1. The first block that we have is the part of the sensors (geophones), this part may have one or three sensors depending the requirements of the final user. These sensors used to acquire seismic vibrations of the volcanic tremors to be converted to electrical signal. Then, the analog signal acquired is sent to the analog-digital converter, where the signal is converted to a digital data. In this module, the signal can be processed with a pre-filter or with a pre-amplification. Finally, this information is send to the microprocessor through Serial Protocol Interface (SPI), where the information is stored and sent.

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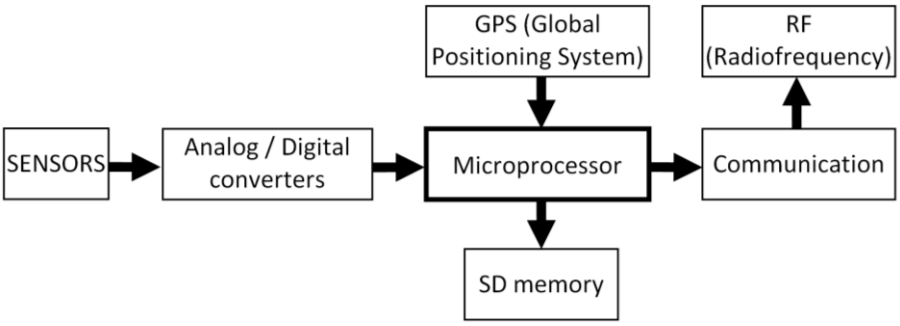

Figure 1. Block diagram of the acquisition system

Specifically, in the microprocessor the data received are packaged before to be stored in the SD memory and before to be sent to the communications module to be transmitted to another node. At the same time the microprocessor must maintain the exact time with a maximum drift of 10ms from the UTC time (Universal Time Clock). In order to keep the timing into the range of drift, the chosen possibility is to synchronize the device with a GPS (Global Positioning System), which is connected to the microprocessor.

III. Acquisition system components

We have made a research of different components, comparing the power consumption of them. The battery is the component with the higher mass of all elements in the system; therefore, consumption and weight are directly related. Then, if we want reduce the weight, but maintain the service life of system, we have to select the lowest consumption components, obtaining for the same service life, lower weight. The result of the study has selected the following devices:

	Manufacturer	Model	Power
Sensor	Input/Output	SM6	0 mW
Converter A/D	Texas Instruments	ADS1246 (x3)	6,9 mW
Processor	Texas Instruments	MSP430F5438	26,7 mW
GPS	SANAV	GM-1315LA	221 mW
Transmitter	LYNX	YLX-TRM8053-025-05	198mW

Table 1. Acquisition system components

To calculate the theoretical power consumption, we have considered the time that should be operating each module of the system in a normal working mode. In case of microprocessor and the A/D converter have been estimated that will be operating the 100% of the day, it is because the system must acquire information in continuously for all time. However, the GPS device is considered to will be connected once a day for 20 minutes to synchronize the base time, and, accordingly, is established a working time of 1.4% per day. Regarding the communication module, we have considered the implementation of three channels of 24bits, 100 Sps and a time frame, for this reason it has been estimated 50% of working time for communication at 19200 bps.

V. Power system

Considering the consumptions of each of the modules and applying the percentage of work for each one, it follows that the proposed equipment consumes around 135.7 mW. At the same time, if we consider the possibility of working without communication module, storing the information in the SD memory, we can observe that power consumption would drop considerably up to 36.7 mW. From this information, we can make a second study to determine the most suitable battery technology for this application. It is important to note that when selecting a battery technology, it should be based on autonomy, cost and weight. Batteries with lower weight and greater autonomy are usually the most expensive.

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As a first approximation, if we prioritize the weight and autonomy, the result shows that the Li-ion batteries have the best ratio to work during a year. With this technology the system would be built with a weighing about 6 kg with the communications module and 1.6 kg without any type of communication. In the following table (table 2), we can see this study based in four different batteries technologies. In this study, we observe how it can vary the final system weight depending on the technology that has been selected. If we consider a life time of one year, we calculate that the system with communications need about 1188.7 Wh and 321.5 Wh without this module.

Technology	Capacity density [Wh/kg]	Efficiency [%]	Weight system with COMM [kg]	Weight system without COMM [kg]
Ni-Cd	44	80 %	27 kg	7.3 kg
Ni-MH	66	66 %	18 kg	4.9 kg
Li-Po	150	99 %	8 kg	2.2 kg
Li-ion	200	90 %	6 kg	1.6 kg

Table 2. Battery technology comparison [4]

IV. Tests and results

The first installation that has been developed is mainly composed by the microprocessor and the A/D converter. In figure 2, we can observe this prototype and the different components that are composed. If we observe the power consumption of this first part of the system, we can observe it consumes about 1.5 mA at 3.3 V, it is a total of 4.95 mW. In the table 1, we can observe that the theoretic power of these two components is of 29 mW, about six times the power consumed in this first test. This consumption is referred to this first test and we have to be aware that the microprocessor is not performing all the tasks to be undertaken eventually, but this data indicates that is following on the right track.

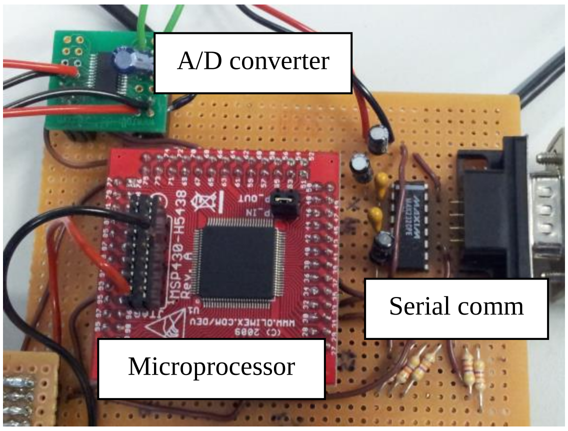

Figure 2. Prototype of acquisition system

At the same time, we create a known sinusoidal signal with a function generator, and the A/D converter module acquires this signal by the sensor's port. Then, the microprocessor reads data of the AD module through a connexion based in Serial Protocol Interface (SPI). Below, the microprocessor sends this information to the computer by standard serial connexion. To visualize that all is correct, we have in the computer an application in LabView program, which represents the data received in a virtual graph. In figure 3, we can observe the signal generated on left picture, and the signal acquired by the computer on right picture.

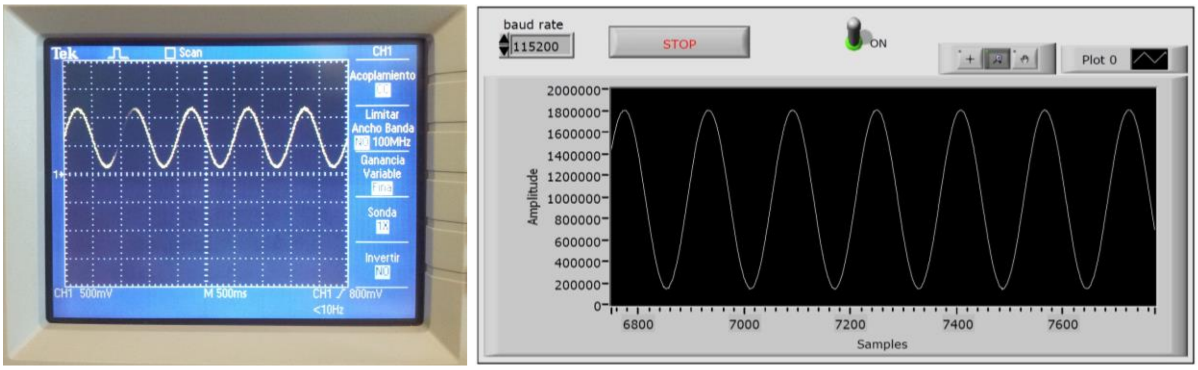

Figure 3. (left) Input signal. (right) Acquired signal in test

The signal generated by the function generator (at left of figure 3) is a signal of 1Vpp, with an offset of 600 mV and a frequency of 1 Hz. In the real situation we may acquire signal between 0.5Hz and 10Hz, so we are within the range. In the graph of the received signal (at right of figure 3), we can observe in the 'X' axis the number of samples acquired, and the 'Y' axis is the quantification of the A/D converter without corresponding volt conversion. Considering that the A/D is working in 160 samples per second, we can observe every period of the 1 Hz input signal is drawn between the corresponding samples.

VI. Conclusions

In this paper presents the results of studies to create a design of a seismic acquisition system for the early prevention in volcanic areas. The proposed design, complies specifications of low cost, low weight and long battery life. The results show the possibility of building a low power system for long service life. The final price for the same autonomy of the system may be higher or lower depending on desired battery technology, being more expensive for lighter weight and more economic for the heavier. Also, we can conclude that the necessity of communicate over long distance has a high energy cost. In the first results, we can observe that these main two components of system have a really low consumption. This shows that we have a margin on consumption, and that we are on track to achieve our goal of create a low power system. In the other hand, in graph we observe how the system sends information in the time and we can assert that the acquisition is correct.

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References

[1] José M. azañón Hernandez, Antonio Azor Pérez, Francisco M. Alonso Chaves, Miguel Orozco Fernández *"Geología Física"*. Ed. Paraninfo. 2002. ISBN 84-9732-021-2
[2] Ramón Ortiz, Alicia García, Mar Astiz *"Instrumentación en volcanología"*. Editor Excmo. Cabildo Insular de Lanzarote. Octubre 2001. ISBN 84-97021-84-0
[3] J. M. Ibáñez, E. Carmona. *"Sismicidad volcánica"*. Instituto de Geofísica. Universidad de Granada. Campus de Cartuja s/n. 18071 Granada. Retrieved on April 2013 http://www.uclm.es/profesorado/egcardenas/SISMICIDAD_VOLCANICA[1].pdf
[4] Saft Baterías S.L. http://www.saftbatteries.com Retrieved on April 2013