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New Directions in Seismic Hazard Assessment through Focused Earth Observation in the Marmara Supersite

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[Long-term monitoring experiment in geologically active regions of Europe prone to natural hazards: the Supersite concept]

D8.4

DESIGN OF THE NEXT GENERATION AUTONOMOUS, MULTI-PARAMETER SEAFLOOR INSTRUMENTATION

TECNICAL REPORT N.1

SYSTEM ARCHITECTURE AND PRELIMINARY TESTS

AUTORS

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Summary

MARSITE PARTNERS

KOERI (Bogazici University, Kandilli Observatory and Earthquake Research Institute)	Turkey
GFZ (Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum)	Germany
TUBITAK (The Scientific & Technological Research Council of Turkey)	Turkey
IFREMER (Research Institute for Exploration of the Sea)	France
INGV (Istituto Nazionale di Geofisica e Vulcanologia)	Italy
IU (Istanbul University)	Turkey
KOU (Kocaeli University)	Turkey
ITU (Istanbul Technical University)	Turkey
CNR (The National Research Council)	Italy
BRGM (Bureau de Recherches Géologiques et Minières)	France
Eucentre (European Centre for Training and Research in Earthquake Engineering)	Italy
CNRS (Centre National de la Recherche Scientifique)	France
INERIS (French National Institute for Industrial Environment and Risks)	France
AMRA (Analysis and Monitoring of Environmental Risk)	Italy
EMSC (European-Mediterranean Seismological Centre)	France
ESA (European Space Agency)	Netherland
Univ. of Pavia	Italy
IFSTTAR (French Institute of Science and Technology devoted to Transport, Planning and Networks)	France
GURALP Systems Ltd	UK
DAIMAR s.r.l.	Italy
SARMAP s.a.	Switzerland

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Introduction

The long-term experience of dealing with geohazards has allowed to improve the scientific knowledge on the development of a natural process (e.g. seismogenesis) and to better understand the signal either physical and chemical due to crustal deformation, crustal ruptures, fluids circulation and release in coincidence of tectonic structures. To gain a better insight into such kind of processes, above the seismogenic process, it is mandatory to collect data on a multidisciplinary base and to give them a common interpretation. As some the natural processes evolve at different rates, the related signals can be recorded on different time scales. Volcanic and tectonic-related fluids have the common feature that they can suddenly change in composition, flow rate, physical properties as a function of the intensity of the temporal development of the natural processes. Stress accumulation in an active fault is a slow process inducing normally changes in the circulating fluids over a similar temporal scale, while the closer is the rupture time, the faster are the related modifications of the fluids (including waters and gases with changes of some parameters over a time-scale from hours to seconds).

To improve our knowledge on the evolution of those processes in a submarine environment we have no other way that to enhance the automatic sea-floor and water column observatories from a technological point of view in order to record as much data as possible from different probes (that means multidisciplinary-type data) over long time intervals. One of the goals of the MARsite project was to design a new generation of sea-floor observatories which is the target of the Task4 in the WP8 of the Project. The report illustrates the activities progress in this field. As it was planned in the DOW, the newly-designed generation of seafloor observatories is able to support the observation of parameters marked by both slow and quick temporal variations. Besides the collection of long-term data set using stand-alone observatories, it is also possible the data collection in real-time or, at least, in near-real-time mode.

The improvement in the quality of the sea-floor observatories includes both the amount of contemporary active probes and the quality of the collected data. That goal has been achieved by the new electronics planned and developed during the conducting period of the project.

Moreover, we selected a submarine site to carry out tests on different items of the observatory. The selected test site is located in the Aeolian archipelago, off the eastern coasts of the island of Panarea, where an active submarine hydrothermal system generates extreme environmental conditions (e.g. very acidic and hot sea water, gas bubbling). The area represents a perfect site to test both the materials used to manufacture the observatory and to record a variety of chemical and physical parameters. In that area, the INGV holds the permission to anchor an infrastructure made of a buoy and a small sea-floor observatory. The infrastructure, deployed as a consequence of the submarine low-energy volcanic explosion of last November 2002, allows the continuous monitoring of some simple parameters (4 temperature probes, a hydrophone, a pressure gauge) for volcanic surveillance purposes. The buoy is able to provide energy (by solar cells) and to connect (by a cable) any equipment deployed at the sea floor with the data transmission system. The shallow depth, only 24 meters, and the vicinity to the coast (less than 2 miles) makes that place a perfect test area.

1. Planning the new electronics

To establish the design requirements of the system, several technical meetings were conducted with researchers working in the field and with experience in the collection and processing of data coming from the marine environment. The electronics designed within the task 8.4 will be the core of the new generation of sea-floor observatories.

A new generation of seafloor observatories should support the observation of both slow and quick variations, thus besides the collection of long-term data set it should enable a data collection in at least near-real-time mode.

The activity of planning, building, testing and deploying a new seafloor observatory may represent a reference for the future technology of submarine equipments, seafloor data collection, storage and transmission.

The development team has studied the problems associated with marine applications, and after scoring and tested many sub-projects, finally it realized a working prototype.

The prototype is made up of various pieces of hardware and software. The most important parts have been developed from the ground up for this purpose, because in the market, were not available components that would provide all the technical characteristics required by the project.

1.1 Prerequisites

The role of the CNR-INGV-DAIMAR development team in MARSite is the improvement of equipments for a new generation of seafloor observatories with the aim of observing both slow and quick variation of long-term data in a near-real-time mode. DAIMAR had the necessary experience to design a new hardware platform to improve the quality of the collected data and to decrease the power consumption in battery-powered applications. The final goal of the collaboration between DAIMAR, INGV, IFREMER and CNR was a list of specification, hardware solutions and laboratory tests on prototype components, to be adopted for the future development of autonomous real-time data collection systems, capable of capturing high definition sounds and multi-parameter data type. In close cooperation with INGV, we has studied the scientific applications of a new generation of data acquisition system. At the end of the first working period, it was decided to focus the attention on the development of a new digitizer and the main technical features have been defined. Many preliminary studies have been conducted through computer simulations and subsystems tests.

The meeting held in Marseille on May 21st and 22nd, 2013 represents a starting point, that generated stimulating discussions between the partners to define a common strategy for the new generation of multi-parameter, sea-floor observatory. IFREMER has proposed to use the new-developed, high-performance, acquisition system, named COSTOFF-2, DAIMAR showed what can be the advantages of a design based on a multi channel "digitizer", in terms of data quality and reduced energy consumption. The hardware planned and produced by development team can be used in conjunction with that developed by IFREMER to expand the possibility of interfacing with analog sensors and optimizing energy consumption of the entire system.

INGV and DAIMAR selected the available marine sensors of wide scientific interest; in particular were selected and studied all the probes produced by the "SEA-BIRD Electronics" company. The selection has allowed DAIMAR to plan a prototype of front-end card to interface the sensors with the 24bit Analog/digital converter.

The above-mentioned sensors are considered as a reference in science and therefore one of the requirements for new data acquisition systems, was the compatibility with the Sea-Bird sensors.

Sensors of interest

SENSORS	Current Consumption (mA)	Power Consumption(mW)	OUTPUT
Temperature (SBE 3 plus)	25	300	Digital – Freq
Conducibility (SBE)	12	144	Digital – Freq
Oxigen (SBE 43)	5	60	Analog
pH (SBE 18)	7	84	Analog
Pressure (SBE 29)	15	180	Analog
Turbidity (Seapoint Turbidity Meter)	3.5	42	Analog
Hydrophone HTI (1Hz-20kHz)			Analog
Hydrophone Reson			Analog
H2S (AMT)			Analog
CH4 (Franatec)			Analog
CO2 (Contros)			Analog

Typical Analog/Digital sensors output

Voltage range	Current range	Digital Freq
+10V -10V	0 mA 20 mA	+0.5V -0.5V 1 kHz 50 kHz

Hydrophone LF bandwidth	Hydrophone HF bandwidth
10 mVpp 1 mHz 100 Hz	10 mVpp 100 Hz 50 kHz

Figure 1: Analog sensors prerequisites

With regard to the fast signals, the focus was on the use of hydrophones for monitoring the flow from submarine gas vents, high frequency seismic vibrations and identification of sound sources with the technique of TDOA (Time Difference of Arrival). From the scientific point of view, there is much interest on the generation of T-waves and T-phases by earthquakes.

T-phases have already proven their usefulness in a number of areas and have potential for extension to others. They have been used to detect volcanism with accuracy suitable for real-time location of volcanic events. Earthquakes that are too small to be recorded by land-based seismometers produce T-phase signals easily recorded by hydrophones, allowing the detection of low-magnitude seismicity. This leads to a better understanding of ridge, transform, subduction, and intraplate processes. In addition the detection of small events associated with larger events allows investigation of stress triggering. T-phase signal content carries information about the earthquake focal mechanism, and the envelope can be used to estimate the focal depth. In the Indian Ocean particularly, T-phases provide a substantial amount of information on earthquake locations as they are in many cases the only available signals. Better understanding of the T-phase source mechanism shows potential for earthquake source tomography with consequent application to plate boundary processes.

The hydrophones can be passive or active and the signal can be either analog or digital. For new systems, it has been required at least an input channel for a passive hydrophone, and the ability to interface with multiple active hydrophones, both analog and digital.

From a software perspective, the most important requirement was that the simplicity and flexibility in software development by programmers. In science, they are used mainly LINUX systems and various programming languages such as C/C ++, PYTON, C-Script, C #, Visual Basic, LabView and a few others. It is therefore important that the hardware platform is easily customized for different applications, so as to leave a wider choice to the programming language.

All of those requirements have been discussed even in terms of reduction of energy consumption. An autonomous system must operate for long time periods, taking its power from a battery pack. The size of the battery packs and the overall system size, has relevant effects on the manufacturing and operating costs of a marine survey. Large sizes involve large volumes, then more weight, oversized submarine containers to reach the required depth, use of large vessels for the deployment and recovery etc ...

For our work, we started from the structure of the INGV GEOSTAR underwater observatories, from which we moved a step forward in terms of energy efficiency, flexibility and reduced costs regarding the central electronic system. The whole idea behind the GEOSTAR project's concept took inspiration from the experience of NASA during Apollo and Space Shuttle missions, where the «two-body» system was a winning approach. Analogously, the architecture of the GEOSTAR Observatory includes a mobile docker vehicle (called MODUS – MObile Docker for Underwater Sciences) and a bottom station. The latter module can run autonomously for long periods (over one year) and it can be employed for abyssal depths (up to 4000 meters).

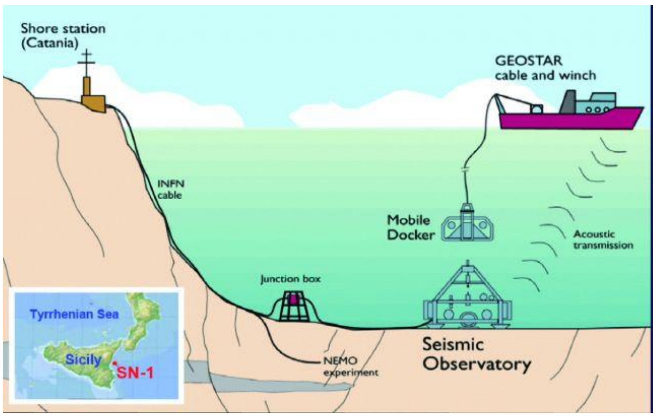


Figure 2: Layout of the NEMO-SN1 underwater structure in Sicily

1. System Architecture

The first innovation relates to the communication protocol we have chosen as standard. It was chosen Ethernet physical layer as technologies for local area networks. Ethernet evolved to include higher bandwidth, improved media access control methods, and different physical media. Ethernet stations communicate by sending each other data packets: blocks of data individually sent and delivered. The User Datagram Protocol (UDP) is one of the core members of the Internet protocol suite. With UDP, computer applications can send messages, in this case referred to as datagrams, to other hosts on an Internet Protocol (IP) network without prior communications to set up special transmission channels or data paths. UDP is suitable for purposes where error checking and correction is either not necessary or is performed in the application, avoiding the overhead of such processing at the network interface level. The Transmission Control Protocol (TCP) is a core protocol of the Internet Protocol Suite. It originated in the initial network implementation in which it complemented the Internet Protocol (IP). Therefore, the entire suite is commonly referred to as TCP/IP. TCP provides reliable, ordered, and error-checked delivery of a stream of octets between applications running on hosts communicating over an IP network.
After considering all the possible conditions of use and all the experimental variables, it has come to the conclusion that the whole system should consist of three main modules: **Power Management System**, **Digitizer**, **Embedded Computer**.
The Power Management System encloses all the electronic components required to provide different levels of power to all electronic sub-systems, including the sensors. This module allows to monitor the power consumption of the system and to enable and disable devices depending on the situation.

The Digitizer plays the most difficult task to convert the analog signals from the various sensors into digital data and supply them to the Embedded Computers for processing and storage on hard disk, or to send to other external devices.
The Embedded Computer supervises all other sub-systems. This is essentially a mini computer that takes care to collect, process and store data and to communicate with all devices using high-level and low-level communication protocols (TCP/IP, UDP, USB, SPI and I2C). The technical details of this module depend on the specific configuration you want to accomplish and the requirements of particular scientific mission.

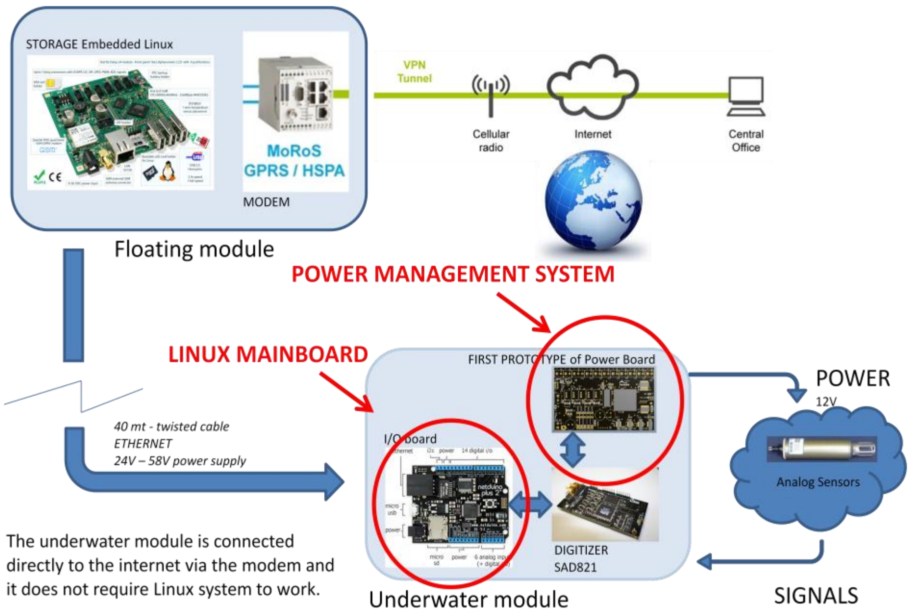


Figure 3: Layout of the first test experiment

The remote communication system is also based on TCP/IP and UDP. We carried out tests with the modem INSYS - GPRS / HSPA MoRoS. The following main functions were very useful for our application :

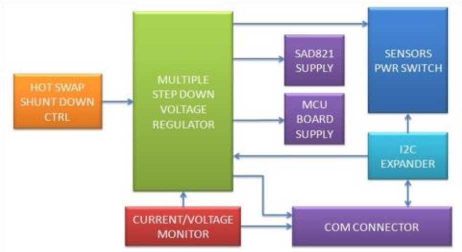
1. The ability to control the relays from the Web. With these switches you can restart the entire system and perform some security functions.
2. The ability to interact with the hardware systems as if they were connected to a local network.
3. The ability to communicate with the computer through the embedded debug port (RS232). In this way, you can have access to the computer's operating system to perform low-level functions.

1.1 Power Management Systems (PMS)

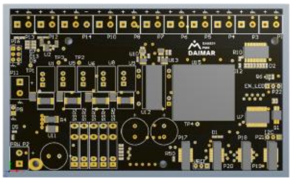
In order to power the different, multidisciplinary probes, the digitizer and the embedded computer, we have designed an electronic board named PMS (Power Management System) with I²C interface .

POWER MANAGEMENT SYSTEM

SAD-821 PMS (Under Development)



SAD 821 - PMS	Output
8 Channels Thermal and Overcurrent Protected	+12V 500mA
1 bipolar channel	+10V/-10V 150mA
2 users channels	12V/ 500mA
DIGITIZER Power supply	3.3V 6.5V 12V
I/O port	15 digital
I2C serial interface	
Voltage and Current monitoring	



2D Rendering of the next version of the Power Board (Under Development)

Figure 4: Power management system board – PMS - block diagram

The board generates the right power supply voltage for the SAD821, a power rail for the sensors and a power supply for the embedded PC.

The board has input (P9) for shutdown. In the shutdown mode, the current consumption is approximately 10-15 μA. Below the main features of the PMS card are summarized:

- Supply voltage between 20V and 58V with overvoltage protection circuit.
- Maximum power supply: 29W
- Maximum current one channel ON: 700mA @ 12V, eight channels ON: 125mA@12V
- Two extra 500mA @ 12V channels for inductive loads
- One bipolar supply 50mA @ +10V, -10V
- I2C bus with the ability to select up to four different addresses
- Power out for the SAD821 digitizer (12V, 6.5V, 3.3V)
- Power out for the Embedded PC (500mA @ 12V)
- Analog outputs for monitoring the total current drawn from the card, the current consumed by PC, the current drawn from the channels CH1-CH8 and the voltage supplied to SAD821 for the digital core (3.3V).

Finally, the board has the ability to disable all led indicators to reduce energy consumption.

The card control can take place via I2C bus or directly by a special connector of I/O with CMOS logic levels (3.3V).

1.2 DAIMAR DIGITIZER (SAD821)

The SAD821 digitizer was developed to get the most in terms of data quality and integration with other embedded systems. Its open architecture allows interfacing with other systems via High-Speed USB or via SPI (Serial Peripheral Interface) low-level protocol.

All internal devices are connected to a single FPGA (**F**ield **P**rogrammable **G**ate **A**rray) that is reprogrammable through a JTAG port (**J**oint **T**est **A**ction **G**roup).

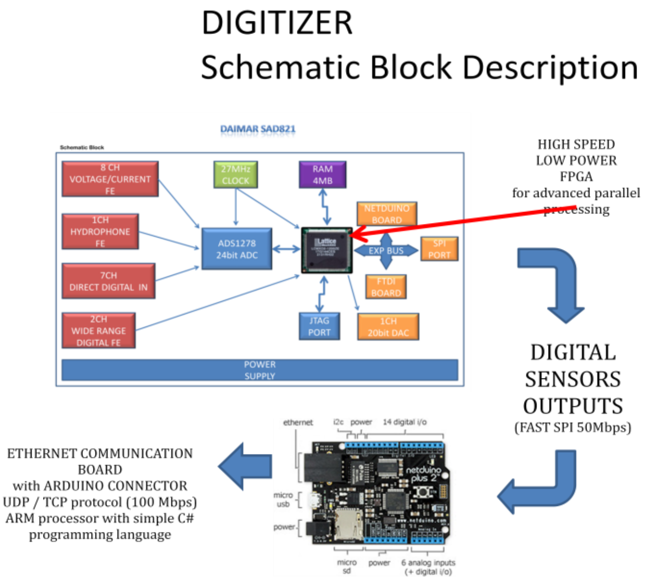


Figure 5: SAD821 block diagram

We made 9 PCB (Printed Circuit Board) and we initially did solder electronic components on three cards. This first series had many problems due to errors during the soldering of the components on the PCB by the company that we have chosen for this task. The small size of electronic components and high integration level, requires a fully automated positioning and soldering process. The second set of electronic cards was fully functional.

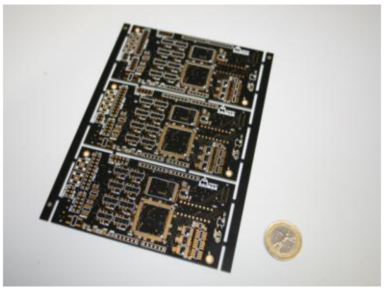
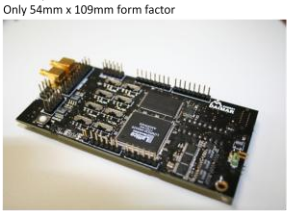


Figure 6: three SAD821 PCB fitted in a panel

DIGITIZER
LOW POWER – HIGH SPEED
8 CHANNELS, 24 bit, SIMULTANEOUS SAMPLING

SAD821
Four Layers PCB with ARDUINO Connector
Only 54mm x 109mm form factor



Experimental measurements of Effective Number of Bits (ENOB)

SAD 821 – rev. 1.0 24 bit, up to 100 kSPS DIGITIZER	ENOB
8 Channels +10V -10V	18
8 channels 0 mA 20 mA	18
1 Hydrophone channel	18
2 Digital-Freq channels	24

1.3 Linux Mainboard

An **embedded system** is a computer with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is *embedded* as part of a complete device often including hardware and mechanical parts. Embedded systems control many devices in common use today. Properties typical of embedded computers when compared with general-purpose ones are e.g. low power consumption, small size, rugged operating ranges and low per-unit cost. Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance.

To communicate with the SAD821 digitizer, an embedded computer must have a SPI communications port. To communicate with the Power Management System (PMS) it must also have an I2C port. These two are the main requirements of the computer to be used to control the system.. All other features are dependent on the particular application specific application. This leaves a lot of freedom of choice on this hardware by the final user.

1.4 ARIA G25

Aria G25 is a cost-effective **S**ystem-**o**n-**M**odule (SoM) thought of to drastically reduce the development time needed to design a low-power and low-EMI Linux Embedded device. The more complex hardware like CPU, RAM, Ethernet, power and EMI components are integrated on a single SMD component in just 40x40 mm (1.57x1.57 inch) using an complex eight layers PCB permitting hardware designers to create their simple and cheap carrier boards.

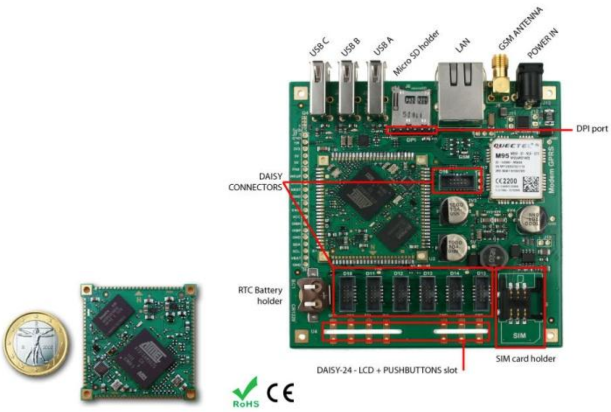


Figura 7: ACME Systems TERRA BOARD with ARIA G25 module

<u>Main Features</u>

- **CPU**: ARM9 @ 400Mhz on Atmel [AT91SAM9G25](AT91SAM9G25) SoC
- **RAM**: 128 or 256 MByte DDR2
- **LAN**: 10/100 Mbit
- **USB**: up to 3 host ports: one hi-speed host/device,one hi-speed host,one full-speed
- **UART**: up to 6 serial lines
- **I2C**: up to 2 I2C buses
- **SPI**: up to 2 SPI buses
- **GPIO**: up to 60 GPIO lines
- **A/D**: up to four channel @ 10 bit

The advantages of embedded Linux over proprietary embedded operating systems include: multiple suppliers for software, development and support, no royalties or licensing fees, a stable kernel, the ability to read, modify and redistribute the source code. The technical disadvantages include a comparatively large memory footprint (kernel and root filesystem); complexities of user mode and kernel mode memory access, and a complex device drivers framework.

1.4.1 RTC

In an autonomous system, you need a RTC (Real Time Clock - Calendar) circuit. Real-time clock ICs measure time, even when the power of the main device is off. During these times, RTC ICs draw power from an auxiliary battery or supercapacitor. As expected, power consumption is a key factor in most RTC designs, but accuracy and small package size are also important. In some applications it is necessary to ensure a high stability and accuracy of the clock. In these cases, any embedded system on the market may be sufficient. One must then use external integrated circuits that significantly increase the energy consumption. Although we have not had the need to use such circuits, the integrated system developed, easily interfaces with external circuits thanks to the embedded computer and digitizer SAD821 based on FPGA.

1.4.2 Energy Consumption

One of the basic requirements, which has led the development the whole system was to keep energy consumption to a minimum. We studied other hardware solutions for reducing energy consumption and identified technical solutions even more extreme. In the first version of the prototype of the integrated system, we wanted to use a standard approach, especially because it was necessary to interface with commercial sensors. In the future, the approach that will ensure better results in terms of energy consumption, it will be to develop from scratch the sensors, trying to work with voltages as low as possible and with digital signals.

Energy is the time integral of power; if power consumption is a constant, energy consumption is simply power multiplied by the time during which it is consumed. Reducing power consumption only saves energy if the time required to accomplish the task does not increase too much. Give power to the hardware devices only when necessary, was the first tasks we have developed both in terms of hardware and software. We recompiled the Linux kernel, to minimize the time to boot and shutdown of the system. From this point of view, replace the Linux operating system with the Microsoft Net Microframework would give better results; the boot would be completed in less than one second. This solution is under study. As regards the storage systems we tested several solutions, starting from solid state hard drives, USB pen drive to the SD-Card. The latter showed the best performance over energy consumption ratio, but for some acoustic applications, the memory size is too small.

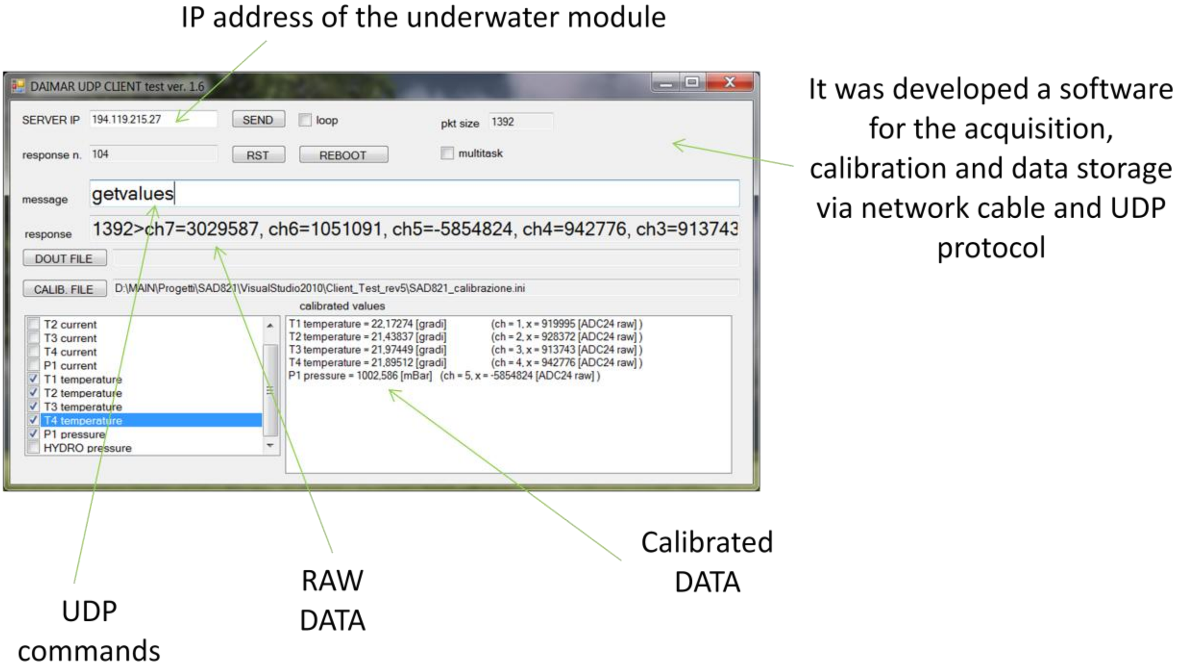
Currently we are working to further reduce power consumption and simplify the development of software applications by users.

2. Software

In the first prototype, all communications between the system and the outside world are via Ethernet connection. In embedded computer (Linux or Netduino Air G25) we have developed a UDP/TCP-IP Server. This server, receives commands via UDP packets, and transmits responses via UDP and TCP-IP packets. The control commands are always simple strings as the answers can be text strings or binary data. To communicate with the remote server, we have developed an UDP Client software that sends commands and analyzes the responses to verify that everything is properly working. The raw data are displayed and converted into physical parameters using appropriate calibration tables compiled beforehand.

The acoustic data can be acquired in binary format and then converted in standard WAV or FLAC format. If the server is installed on Linux, you can receive data directly in WAV or FLAC.

FLAC (Free Lossless Audio Codec) is an audio coding format for lossless compression of digital audio, and is also the name of the reference codec implementation. Digital audio compressed by FLAC's algorithm can typically be reduced to 50–60% of its original size and decompressed to an identical copy of the original audio data. FLAC is an open format with royalty-free licensing and a reference implementation which is free software. FLAC has support for metadata tagging, album cover art, and fast seeking.



The software was written in C #, with the free version of Visual Studio, for both the server and the client on Windows. To run the code on Linux, we used "Mono". Mono is an open source implementation of Microsoft's .NET Framework based on the ECMA standards for C# and the Common Language Runtime. Mono is primarily developed on Linux, and most of its users are Linux users, so it is the platform best supported.

During the tests conducted in the laboratory, many other applications have been developed using LabView. LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments. LabView is very useful to graphically display the acquired data and to help find possible errors.

2.1 Data Presentation and Analysis

INGV researcher developed a custom Client which was installed on the floating module with the aim to set-up scheduled daily acquisition an simply interact with the UDP/IP server. Exploiting the Client/Server paradigm to obtain data over Ethernet connection let the lower layers become transparent from the application layer. Thus, the client can perform tasks that are independent both of the locations of the data, and of the system on which an operation is carried out. Additionally sensor configuration is simplified because of the abstraction level given by the server. Once raw data are collected, the client performs post-processing and stores physical data locally. Together with samples coming from the underwater module , the software collects also GPS position, meteorological and diagnostic information directly by the floating module during the day. All processed data are available through a web page and can be downloaded at any time.

In addition to that, a central remote server has been developed by INGV to periodically receive processed data from the floating module and store them in a more structured and efficient way via DBMS (short for DataBase Management System). As a result, the stored information can be published via a dynamic web site which allows users to analyze data graphically, providing interactive means to compare data, to better understand the trends and quickly investigate hypothesis. The following figures show some of the data acquired during the field tests carried out in 2014, enlightening how data can be easily interpreted from the server web site.

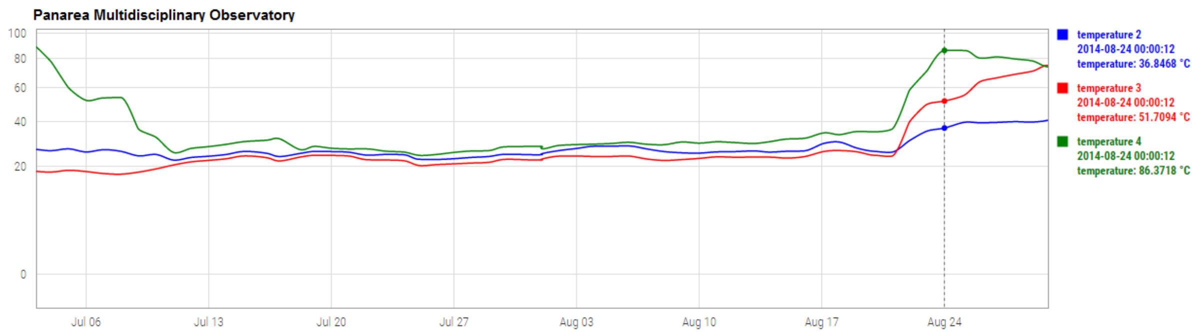


Figure 8: Temperature changes in a hydrothermal vents detected by one of the analog sensors (above) and by all the sensors (below) - (thanks to Gianluca Lazzaro and Andrea Corbo - INGV)

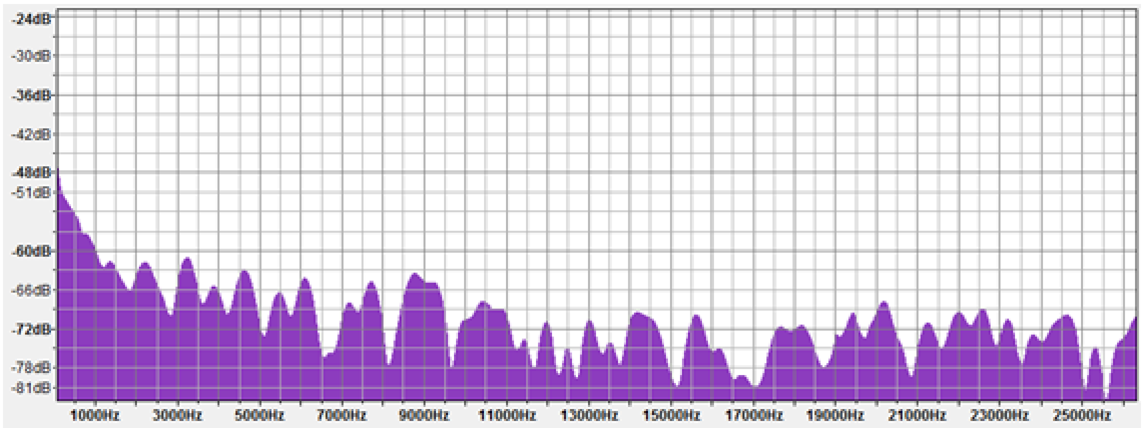


Figura 9: Example of data elaboration from the hydrophone in terms of frequency and intensity automatically produced by the software - (thanks to Gianluca Lazzaro and Andrea Corbo - INGV)

3. Test in Marine Environment

We integrated the three main components of the system (DIGITIZER, POWER MANAGEMENT SYSTEM, LINUX EMBEDDED COMPUTER) in a single optimized frame. The first prototype of the digitizer was built. All laboratory tests necessary to verify the correct operation of the hardware have been performed. All the necessary firmware for the FPGA and the software for embedded LINUX computer were written. To test the system under real conditions, all parts were integrated inside a submarine vessel. Four temperature sensors, a pressure sensor and a hydrophone have been connected.

The first tests were conducted at the Institute for Coastal Marine Environment of the National Research Council in Cape Granitola (TP). We tested the complete system in the marine environment to correct any bugs and add new software features. During the tests (February-March 2014) we have acquired acoustic signals at regular time intervals for a period of about 30 days.

Data has been acquired for about 30 days and were subsequently analyzed. The tests showed that the system works properly and can be used in real experiments.

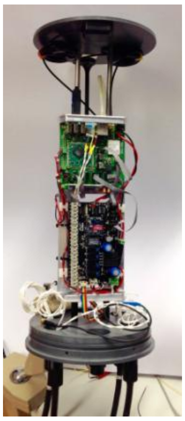


Figure10: Assembled Prototype

At the end of experiment, we have also made changes to the FPGA firmware. In particular we have added the ability to accurately measure frequency signals.

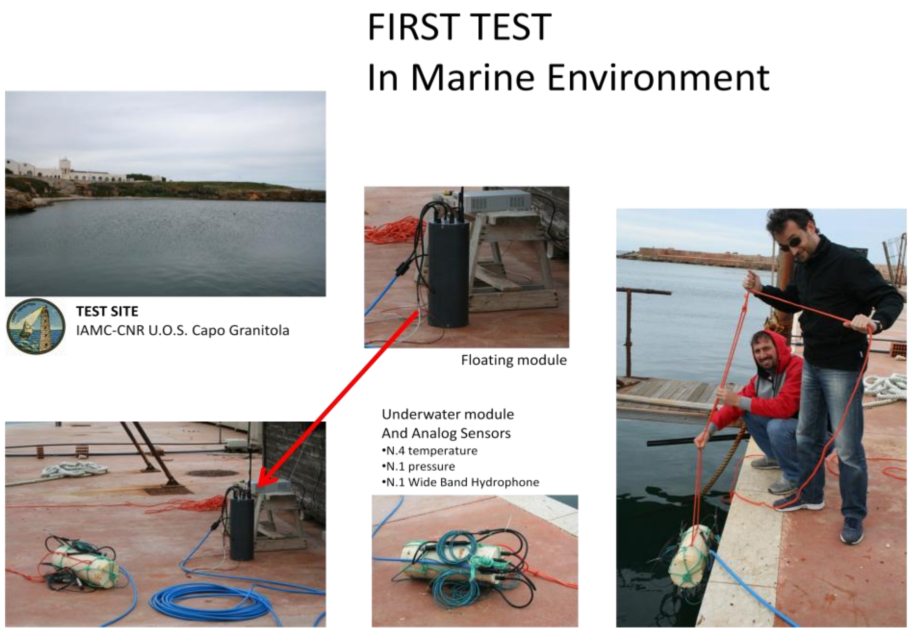


Figure11: First test at Cape Granitola at the IAMC-CNR

3.1 The PANAREA Test Site

The Panarea test site is an extreme submarine environment located at shallow depth off the eastern coast of the island of Panarea, a volcanic island where in November 2002 a low-energy submarine blast occurred. The site is characterized by the widespread presence of hydrothermal vents that release acidic hot waters (up to 140°C) and CO_2-dominated gases. Due to the wide spectrum of physical and chemical phenomena (changes in the sea-water characteristics, noise due to the submarine bubbling, changes in the gas flow rate etc), the area (about 4km^2-wide) is an excellent and easily accessible test site, where experiments can be carried out by scuba divers at shallow depth (average depth about 20m) or by oceanographic vessels a few miles away at depth up to 2000m.

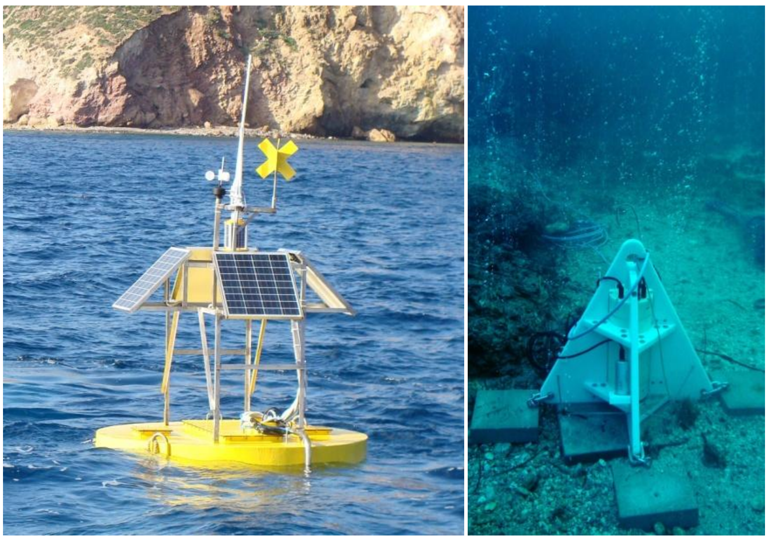


Figure12: INGV buoy and sea-floor observatory located at the Panarea test site. The system is being working since July 2007

INGV holds and maintains an experimental system consisting of a surface buoy connected by an umbilical cable to an underwater module. The buoy is able to take the data from the sea-floor station and to send them in near real-time by an UMTS module. That system has been used to jointly test all the items developed by the team. The sea-floor observatory equipped with Daimar cards was connected to analog sensors made of four temperature probes, a pressure sensor and a hydrophone. The sensors were selected in order to have both slow and fast parametric variations to evaluate the performances of the system in different conditions of use. The test lasted three months (from July to September 2014) during which data have been collected and sent to a server. Using a web browser, data were then downloaded to local computer for analysis. The system included the ability to update the software remotely. In this way, we fixed some bugs.
The software for WEB data exchange was developed by INGV, in close cooperation with CNR and Daimar, in order to enhance the capabilities of the newly developed electronics.

4. CONCLUSIONS

The work done within the task 4 of the WP 8, led to the development and implementation of a hardware and software architecture that could be used as a basis to build up the next generation of sea-floor observatories.
The flexibility in the choice of the software development environment, the reduced energy consumption, the small size of the electronics boards and the ability to interface to a wide range of analog and digital sensors as well as the new solutions for power feeding make the use of the new architecture the reference for the next generation of sea-floor observatories especially when compared with the complexity and costs of implementation of the previous generation.
In the design phase, we took into account the current needs of researchers, but we also tried to develop solutions that will allow further development of the system in an easy way.
The presence in the market of always new electronic components, with progressively lower energy consumption and with increasingly high performance, makes it necessary the periodical updating of the hardware, in order to acquire data of higher quality, for longer time intervals and at a lower cost.
The OPEN architecture developed by CNR and DAIMAR, enables fast updating of the system without having to redesign the entire infrastructure. Although the software can be easily developed by the researchers, who will have a well-documented hardware platform on which to work. The collaboration between CNR, DAIMAR and INGV, allowed to outline the guidelines for a new "OPEN HARDWARE" for marine research.