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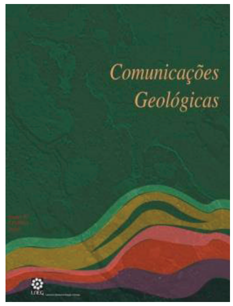
CIVISA´s seismic network migration from analogue to digital through an affordable data acquisition system and radio Wi-Fi telemetry design



Migração de analógico para digital da rede sísmica do CIVISA mediante o desenho de um sistema de aquisição de dados e um rádio telemetria Wi-Fi

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Abstract: In September of 2016 a new digital communications network for the Azores Civil Protection (SRPCBA) was inaugurated providing digital, voice and Ethernet LAN telemetry capabilities to the Centre for Information and Seismovolcanic Surveillance of the Azores (CIVISA). During 2017, the telemetry links from all monitoring techniques were reconnected to the new communication system. In 2018 the CIVISA has started the migration from analogue to digital seismic stations and this process allow to liberate few short period geophones. At the CIVISA's Information and Communication Technologies Support group (SATIC), motivated by the availability of sensors, an instrumentation project was started with the objective of develop affordable digital data acquisition system (DAS) for geophones and a Wi-Fi telemetry to transmit seismic data to the Data Acquisition Centre (CAD) of CIVISA, in Ponta Delgada. The DAS design uses Do It Yourself (DIY) modules for Internet of Things (IoT) applications, microcontrollers and low power computer boards.

Keywords: Telemetry, seismic, digital, migration, geophone.

Resumo: Em setembro de 2016, foi inaugurada uma nova rede de comunicações digitais para o Serviço Regional de Proteção Civil e Bombeiros dos Açores (SRPCBA), fornecendo capacidades de telemetria digital e voz ao Centro de Informação e Vigilância Sismovulcânica dos Açores (CIVISA). Em 2017, os enlaces de rádio das diversas técnicas de monitorização passaram para o sistema atual. Em 2018, o CIVISA iniciou a migração das estações sísmicas analógicas para digitais e este processo libertou alguns geofones. No grupo de Serviço de Apoio às Tecnologias de Informação e Comunicação (SATIC), motivado pela disponibilidade de sensores, iniciou-se um projeto com o objetivo de desenvolver um instrumento de aquisição de dados acessível (DAS) para geofones e um rádio Wi-Fi para retransmitir dados para o Centro de Aquisição de Dados (CAD), em Ponta Delgada. O DAS utiliza dispositivos Do It Yourself (DIY) para aplicações de Internet de Coisas (IoT) e computadores de baixa potência.

Palavras chave: Telemetria, sísmica, digital, migração, geofone.

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1. Introduction

In September of 2016, a new digital communications network for the Azores Civil Protection (SRPCBA) was inaugurated, increasing voice and digital data communications between all the Civil Protection Authorities and its staff (Cabral, 2018). This system provides digital voice and Ethernet LAN telemetry capabilities to the Centre for Information and Seismovolcanic Surveillance of the Azores (CIVISA). During 2017, the telemetry links from the seismovolcanic network, constituted by a total of 37 seismic stations, 36 analogues and 1 digital, and other different monitoring techniques were reconnected from the old to the new communication system.

To obtain the benefits of this new infrastructure, the CIVISA has started in 2018 the migration of its analogue seismic stations to digital ones. At least 12 broadband sensors will be deployed in the next three years, replacing some analogue short period seismic stations. This improvement will generate a stock of few short period geophones and its respective signal conditioners.

Motivated by the availability of sensors and previous experiences in instrumentation the CIVISA's, SATIC group has began a new project with the objective of developing an affordable digital data acquisition system (DAS) and a Wi-Fi radio for telemetry to communicate between remote sites and the nearest civil protection facilities, to relay seismic data to the Data Acquisition Centre (CAD) of CIVISA, in Ponta Delgada.

2. CAD Seismic signals process

At the CIVISA's CAD, both analogue and digital seismic signals are received. Most of the seismic network, including the digital station, uses LE-3D, 1Hz 136dB short period geophones as shown in figure 1a. The signal of a digital seismic station is transmitted in the form of time stamped data packages with 144 dB of dynamic range.

However, analogue stations provide most of the seismic network covertures used for magnitude calculations and volcanic monitoring

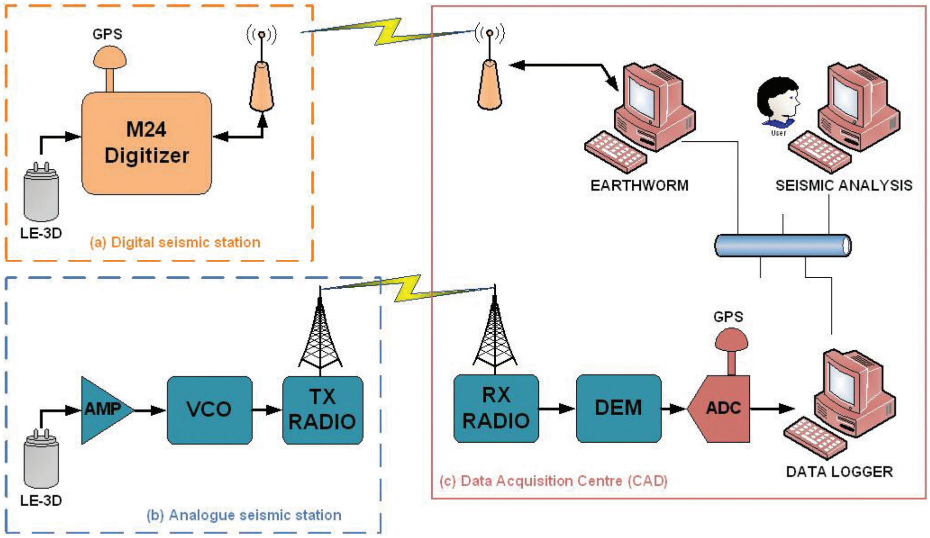

Figure 1. CIVISA's Seismic Network and CAD facilities schematic diagrams: (a) digital station; (b) analogue station; (c) CAD.

Figura 1. Diagramas esquemáticos da rede sísmica do CIVISA e instalações do CAD: (a) estação digital; (b) estação analógica; (c) CAD.

(Fig. 1b). Due the analogue signal conditioning and telemetry, the dynamic range is drastically compromised. The signal data acquisition is performed by a National Instruments 16-bit (96 dB) analogue to digital converter with a resolution of 0.3 mV/bit with GPS clock synchronization that feeds a data logger software for recording and data sharing in standard formats such as miniSEED. Remote and locally digital signals feed the Earthworm (EW) seismic software for automatic and manual processes such storage, picking, magnitude and location (Fig. 1c). A group of seismic specialists, working 24/7 all year, are responsible for processing seismic and other techniques data, producing alerts and reports for the different authorities.

3. Data acquisition system, DAS

As previously mentioned, analogue telemetry and local digitalization reduces the dynamic range that can be obtained from the geophone. The solution is that the remote digitalization can be achieved by the purchase of a commercial DAS, but this is not easy to accomplish because of the budget. Therefore, it is necessary to find new economical viable instrumental solutions that can be useful to reuse geophones that are available.

An affordable instrumental solution is the current project for a DAS based in the combination of two electronic circuits: one data acquisition (DAQ) module with three channels, and one data signal processing (DSP) device (Fig. 2).

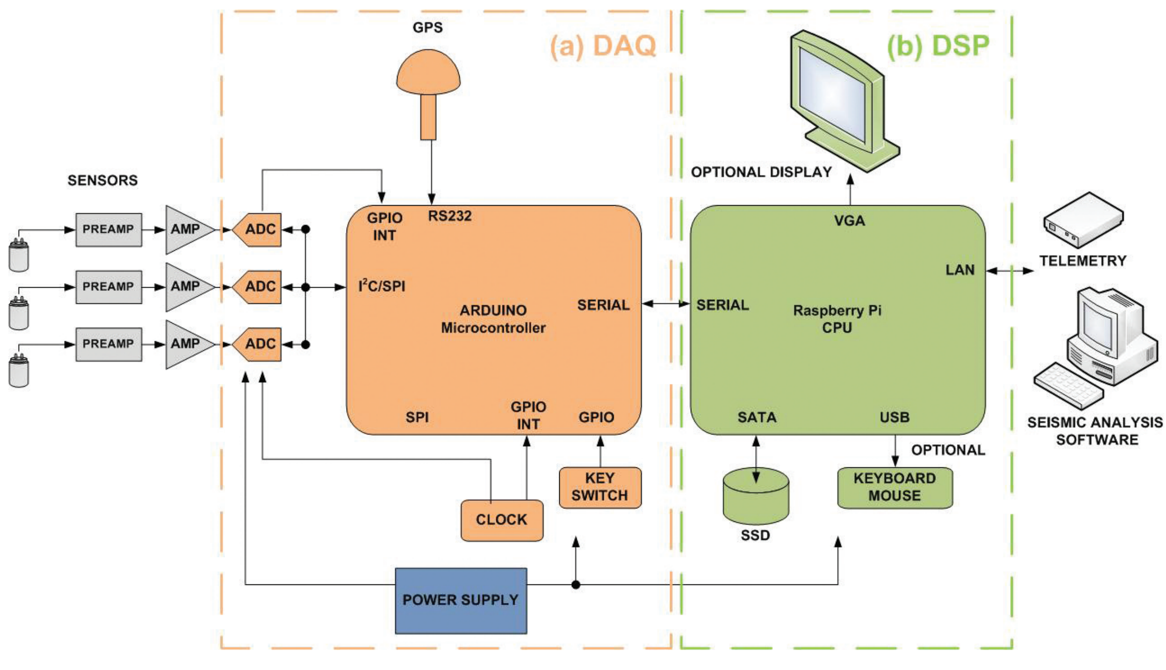

Figure 2. Three channel DAS integrated in the seismic network pipeline: (a) DAQ module; (b) DSP.

Figura 2. DAS de três canais integrados no pipeline da rede sísmica: (a) módulo DAQ; (b) módulo DSP.

The core of the DAQ (Fig. 2a) is composed by an integrated circuit (IC) ADS1115 of 16 bits (96 dB) sigma-delta technology analogue to digital converter, a microcontroller ARDUINO™ and a GPS DIY module for time stamp. The module is capable to convert the three analogue signals up to one-hundred samples for second (sps) with no missing codes.

The DSP section of the DAS (Fig. 2b) is intended for permanent data storage and seismic data server compatible with EW and other seismic software. A Raspberry Pi Linux based small 12 V computer is used for these functionalities; however, other low power micro-computers boards can be used.

Communication and timing data frames between DAQ and DSP are compatible with TAMBOR_DIGITAL recorder software (Ortiz, *et al.*, 1992). This increases the DAQ module versatility allowing local data recording or analogue station digitalization when connected to a personal or portable computer.

4. Wi-Fi radio telemetry

In 2008, through the collaboration between the CIVISA and the Institute of Geophysics of Hamburg University, a new dual band Wi-Fi radio was developed for multi parameter digital telemetry. The radio main components are two electronic boards, a Linux operative system and accessories such as compact flash card, connector's pig-tails and aluminium housing.

The first board is an ALIX board from PC Engines™ model ALIX3D2 (Fig. 3a) designed for Wi-Fi routing applications, and the second one is a MikroTik R52NH-350 wireless 802.11a+b+g miniPCI dual band card capable to transmit with 25dBm (Fig. 3b). The first experiment occurred in late 2008, for Doppler radar system in the Fuego Volcano, in Colima (Mexico). The radios pair was able to cover a distance of 28 km. The most recent experience is running at Santa Maria Island (Azores, Portugal) in a piezometer network (Fig. 4).

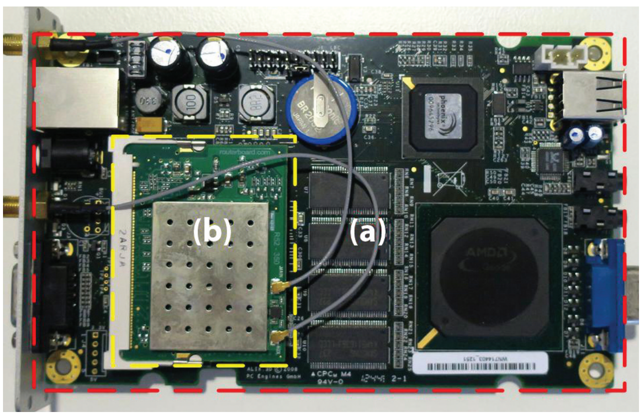

Figure 3. Wi-Fi radio electronic boards: (a) ALIX3D2; (b) R52NH-350.

Figura 3. Placas eletrónicas do rádio Wi-Fi: (a) ALIX3D2; (b) R52NH-350.

5. Present work and results

One electronic experimental board, with four ADS1115 modules (8 full differential channels) and one real time clock, was built in order to proceed with laboratorial tests (Fig. 5). An initial experimentation was conducted to verify each component of the circuit using an i²c scanner program (Bang, 2017).

To reduce programming effort, the Nanoshield_ADC library (NanoShield_ADC, 2018) for the data converter module was se-

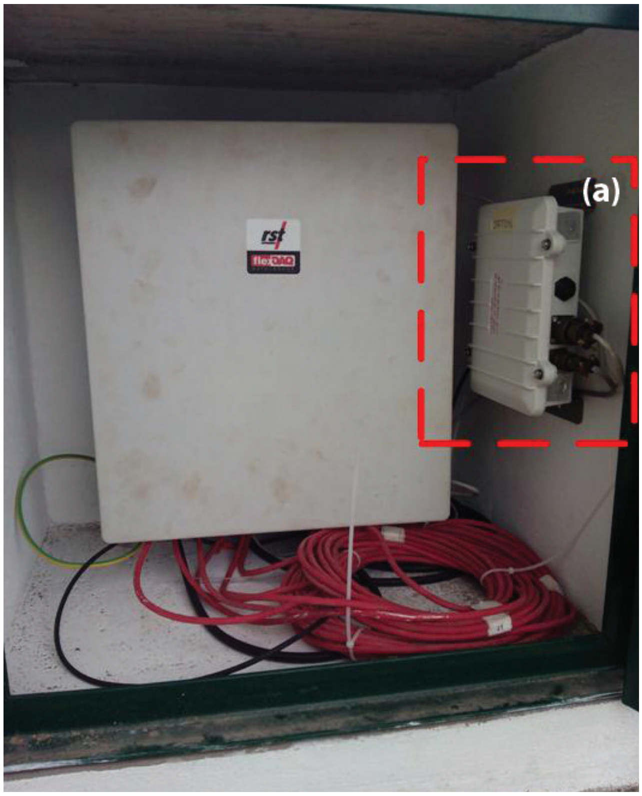

Figure 4. Piezometer data logger shelter with the Wi-Fi radio (a).

Figura 4. Abrigo do registador de dados piezométricos com rádio Wi-Fi (a).

lected. A program to experiment a single channel in continuous mode was written and used to digitize a 100 mVpp, 1 Hz signal generated by an arbitrary function generator (Fig. 6).

The result chart in figure 7 shows some erroneous values producing some signal distortion. Using the library, the data converter is capable to produce a sample each 4 ms (250 sps) but increases wrong reading values.

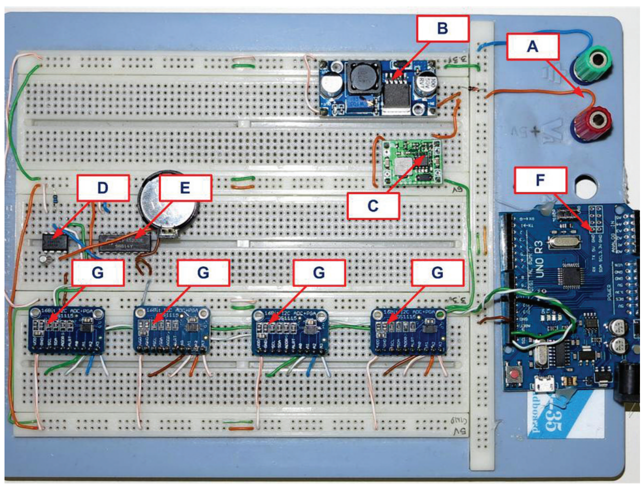

Figure 5. Electronic experimental board: (a) Electrical terminals; (b) 3.3 Vdc power supply; (c) 5 Vdc power supply; (d) DS1307 clock; (e) Binary counter; (g) ADS1115 data acquisition modules.

Figura 5. Placa de experimentos eletrónicos: (a) terminais elétricos; (b) fonte de energia de 3,3 Vcd; (c) fonte energia de 5 Vcd; (d) relógio DS1307; (e) contador binário; (g) módulos de aquisição de dados ADS1115.

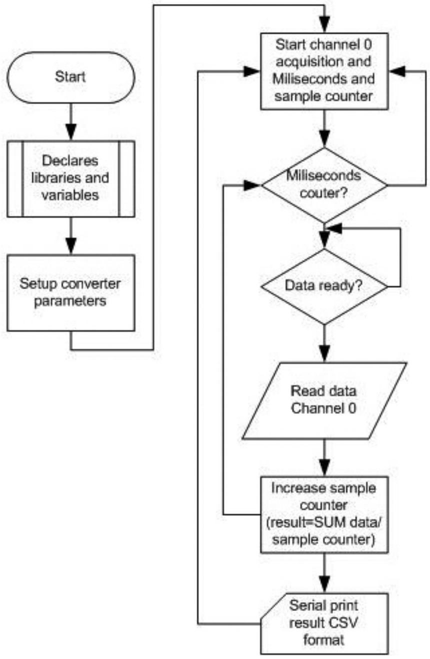

Figure 6. Flux diagram for one channel data acquisition program.

Figura 6. Diagrama de fluxo do programa de aquisição de dados para um canal.

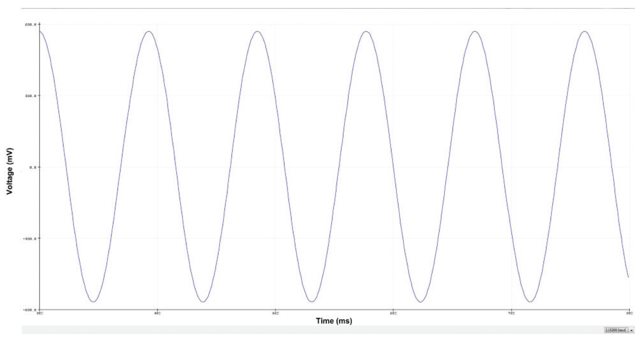

Figure 7. Signal acquired with the differential single channel program.

Figura 7. Sinal adquirido com o programa para um canal diferencial.

A new program for eight differential channels based in the previous one was written, and the first results are promissory (Fig. 8). A 31 sps sample rate per channel was achieved. This sampling rate can be sufficient for low frequency applications such as tilt-meters, infrasounds, volcanic seismic arrays, etc. To increase it will be performed library alterations and the ALERT signal from each ADS1115 will be used.

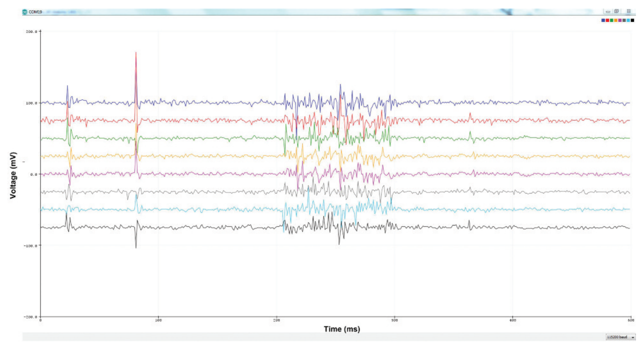

Figure 8. Records of the 8-channel acquisition experimental board with a 4.5 Hz geophone.

Figura 8. Registo dos oito canais da placa experimental de aquisição com um geofone de 4,5 Hz.

6. Future work

The DAQ's data converter IC requires hardware and software modifications to achieve the 100 sps without misfit values. The implementation of the physical pin Data Ready and modification of the ADC´s libraries will be experimented to achieve this goal. Because the ADS1115 module has two different channels, two modules are required for one geophone, leaving the DAQ with an extra channel. A new reading value will be introduced. The state of health (SOH) reading will be implemented for low sample rate battery monitoring.

Regarding the Wi-Fi telemetry, and even that the CIVISA's Wi-Fi radio has demonstrated to be a robust telemetry device, some improvements can be implemented such as MESH node capabilities and WDS protocol.

New commercial boards with a low consumption and a most friendly software interface are now available and can be useful for the CIVISA´s monitoring networks. Before the end of 2018, the purchase of a pair of this 5 GHz cards and antennas it's planned, and a 14 km radio link test between CIVISA and *Agua de Pau* volcano will be conducted.

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