Development of a prototype for submarine communications in shallow waters

Luis A. Mariscal Rico(1), Leopoldo Gómez Castillo(1), Eugene Rychkov(1), Manuel Figueroa Recio(1), Alfonso Corzo Rodríguez (2), Julio Bohórquez Ferrando (2), Sokratis Papaspyrou (3)
(1) Telecommunications Marine Laboratory, University of Cadiz, Research Institute CACYTMAR, University campus of Puerto Real, 11510, Puerto Real, Cadiz, Spain
(2) Microbial Ecology and Biogeochemistry Laboratory, University of Cadiz, C.A.S.E.M., University campus of Puerto Real, 11510, Puerto Real, Cádiz, Spain
(3) Area of Microbiology, Department of Biomedicine, Biotechnology, and Public Health, University of Cadiz, 11510, Puerto Real, Cádiz, Spain

***Abstract** – The Telecommunications Marine Laboratory (TML) of the University of Cádiz takes part in a research project to study the intertidal sediments of the Bay of Cádiz. The collection of samples from the seabed and the transmission of data to the surface are performed by a Mini Profiler with four channels (MP4), which is supplied by UNISENSE. Each channel processes the samples collected by a single sensor. For power, control, and data transmission, a special wiring that connects the submerged subsystem with the surface subsystem is used. The tension transmitted by the cable to the MP4 structure makes its handling and positioning under water more difficult. This article explains the technological solution developed by the TML to replace some wiring from the MP4. For the prototype, two underwater acoustic modems have been used and an electronic system has been developed based on the Arduino platform, in order to multiplex, digitize, and transmit the data collected by the MP4 sensors, eliminating the need to use wiring. The submerged subsystem has an autonomous power supply by a battery.*

***Keywords** – modem, DAC, ADC, sensor, propagation.*

I. INTRODUCTION

The MP4, which is distributed by UNISENSE, consists of two subsystems. One is composed of the elements found on the surface and the other consists of those immersed. The Fig. 1 describes the data flow from the sensors to the computer system.

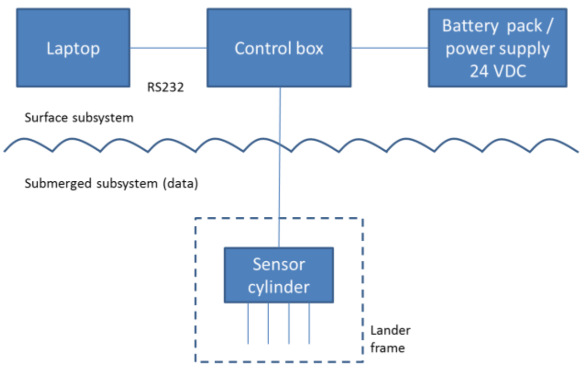

Fig. 1. Block diagram of the Mini Profiler's data subsystem

Currently, the umbilical cable connecting the control box to the cylinder containing the sensors and analog amplifiers supports the transmission of a set of signals. On the one hand, the power down signal (two wires); and on the other hand, the upstream data signals (four wires, one per channel). The data signal generated by a sensor (electrical current or voltage) has a very small value. Due to this fact, it is necessary to amplify said signal before sending it to the surface. The sensor group cylinder container has a channel amplifier that amplifies the signal corresponding to about 60 dB before injecting it into the umbilical cable. The signals from the cylinder are digitized on the surface in the control box by an analog-digital converter (ADC) of 15 bits, and sent to a computer via RS232 for further processing.

Two improvements were identified in the MP4 for further operation of the system. Firstly, the elimination of the umbilical cable and, second, the scanning data signal near the source. The TML has made and validated a prototype to assess the technological solution that allows us to obtain the proposed improvements.

II. SYSTEM DESCRIPTION

To implement the aforementioned improvements, it is necessary to consider which part of the surface subsystem in charge of data transmission should be transferred to the dipped subsystem. In Fig. 2 the chosen solution can be seen, which replaces the umbilical cable by the wireless link between the acoustic modems, and moves the data processing system -made in the box control- and battery to the submerged part.

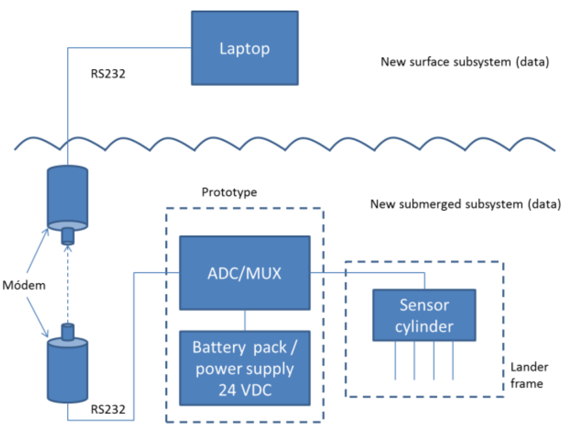

Fig. 2. Block diagram of the modified data subsystem

The new data processing system consists of an ADC per data channel and a multiplexer (MUX) to go from four channels to one. The system connects to the submerged modem via RS232. Data from the sensors are passed through an amplifier before entering each ADC to ensure an appropriate range of input amplitudes. The ARDUINO

UNO platform [1] was selected for the interconnection of all the elements that form the data processor. A set of voltage regulators provides power to the various elements of the submerged subsystem, including modem and cylinder sensors.

On the surface, the modem is connected to the computer system via RS232. The received signal is processed by a Python program that performs channel demultiplexing and digital-analog conversion (DAC) of their output signal. Finally, the program transforms the processed data to recover their initial range of values. The program allows for a pre-calibration of each data cannel.

II. ADC / MUX DESIGN

To adjust the amplitudes of the output signals of the sensor cylinder, a circuit based on an operational amplifier has been designed. The cylinder contains four sensors with their corresponding signal amplifiers. Each sensor responds with a peak current or voltage whose values are proportional to the measured value (e.g., pH) physicochemical variable. These values are in the range of ±0.5 mV. The channel amplifier applies a gain of 60 dB to the signal generated by the sensor. Thus, the range of amplitude values of the output signals of the cylinder becomes ±0.5 V. The ADC used is ADS1115 [2], which is configured for an input range of 0 to 4.096 V, so it is necessary to insert an amplifier to the input of each channel to adapt the signal levels before the corresponding ADC. The Fig. 3 illustrates the circuit described.

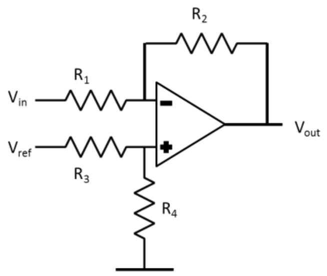

Fig. 3. Amplifier with setting output medium level.

The resistor values are calculated to have an output range, in each case, included in the input range of the ADC, by (1)

$$V_{out} = -V_{in}(R_2/R_1) + V_{ref}(1 + R_2/R_1)/(1 + R_3/R_4) \qquad (1)$$

The reference voltage V_{ref} allows focusing the output voltage V_{out} within the range of the ADC. Due to the tolerances of the resistors, the nominal output amplitude range of each amplifier has been reduced, to avoid saturation in the ADCs. Specifically, the calculations are performed following the same method for each amplifier, to achieve an output range of 0.3 to 3.7V. The LM324 [3] circuit, which consists of four operational amplifiers, has been selected for the purpose.

The circuit ADS1115 includes four 16-bits ADCs -a sign bit and 15 magnitude bits. With the configuration noted above, it has up to 32 768 quantization levels, which provides a sampling resolution of 125 microvolts. The ADS1115 also provides multiplexing of four data channels, which optimizes the number of system components.

The multiplexed data are given to ARDUINO for transmission by the modem. Since the modem has an RS232 connection for data input and output, an interface between ARDUINO and the modem is inserted to adapt the output and input formats of the signals. After several tests, the MAX232 circuit [4] was selected.

III. MODEM AND BATTERY

The modems used for system validation are the S2CR 18/34 model by EVO LOGICS [5]. This is a type of acoustic modem with an omnidirectional broadcast pattern and data transfer capacity of up to 13.9 Kbits/s. The maximum working depth is limited to about 200 m (housing made of delrin).

Once the actual consumption at full load is measured, the submerged subsystem capacity necessary to provide the system with a range of several hours of battery power was calculated. Finally, a LI-ION 24V 2.6Ah battery was selected.

IV. SYSTEM APLICATION

The modem connected to the surface subsystem delivers the data received from the submerged modem to the computer. To manage the flow of incoming data, a code in the Python programming language has been developed. The code demultiplexes the four channels and converts the encoded data into voltage values. That is, through this program the inverse ADC / MUX submerged subsystem functions are performed. Finally, the voltage values obtained are processed to calculate actual values of voltage, delivered by the cylinder sensors to ADC / MUX, considering amplification and translation by these values.

The tolerances of the components are compensated by the calibration process and the necessary information is obtained to reset the parameters entered in the program. Thus, the calibration is performed by the program rather than physically adjusting the value of any component of the ADC / MUX.

The program is set up so it can access the serial port to which the modem is connected to and read the received data. Once the port is accessed, the program generates an Excel file where modem data are kept indicating the date and time of receipt.

V. EXPERIMENTAL RESULTS

For prototype testing, the water tank facilities from the TML (Fig. 4) were used. The tank is 4 m long, 2.5 m wide and 1.5 m high. Because of the echoes of the signals from the sides and the bottom of the tank we had to bring the modem to a distance for which the multipath effect was negligible.

Battery and ADC / MUX were kept out of water for this test, as in the current development phase the objective is to validate the link point to point.

The result obtained in the calibration of one channel sensor cylinder is presented; more specifically, the one corresponding to the oxygen sensor. This channel presents a range of voltages to the amplifier output of 0 to 0.5 V. The sensor signal is simulated by a precision power supply available in the LTM. The source was connected to the ADC input of the corresponding channel ADC / MUX.

Fig. 4. Experimentation tank (CACYTMAR)

A range of input voltages to compare with readings PYTHON program was selected. The results are shown in Table 1.

Table 1. Results for Oxygen channel (values in volts)

v_{in}	v_{python}	v_{python}-v_{in}
0.000	-0.0001	-0.0001
0.050	0.0500	0.0000
0.100	0.1001	0.0001
0.150	0.1501	0.0001
0.200	0.2000	-0.0000
0.250	0.2501	0.0001
0.300	0.2999	-0.0001
0.350	0.3500	-0.0000
0.400	0.4001	0.0001
0.450	0.4498	-0.0002
0.500	0.5001	0.0001

As can be seen, the differences between the pattern signal (v_{in}) at the input of the ADC / MUX and the detected and processed signal in the computer area (v_{python}) are in the order of hundreds of microvolts (decimal places). The error can be justified by the quantization process of the signal, because the sampling interval is 125 microvolts. The results obtained in the other channels are similar, which validates the technological improvement proposal for the MP4.

REFERENCES

[1] https://www.arduino.cc/en/Main/ArduinoBoardUno
[2] http://www.ti.com/lit/ds/symlink/ads1115.pdf
[3] http://www.ti.com/lit/ds/symlink/lm124-n.pdf
[4] http://www.ti.com/lit/ds/symlink/max232.pdf
[5] http://www.sidmar.es/S2CR-18-34.html