Table 1. Comparison of calculated results by different definitions

	Wave (m)	Wind (m/s)	Current (m/s)	Phase angle	Max DOF (m)	Max Stress (MPa)	Joint Return period (yr)
1	8.63	39.90	1.24	58°	0.3088	0.118e9	150
2	8.63	56.04	2.37	58°	0.5146	0.194e9	500
3	6.91	45.86	1.50	58°	0.2355	0.927e8	100
4	8.72	45.86	1.50	58°	0.3507	0.133e9	180

Table 2. Comparison of calculated results by traditional addition method and MCEVD

Traditional addition method	H_s (m)	Crest height with 100 return period yrs (m)	Surge with 100 return period yrs (m)	Tide & Air gap(m)	Deck elevation above *LAT*(m)
	5.53	3.69	1.85	2.45+1.5	9.49
MCEVD method	Joint probability of 100-yera return period				
	H_s (m)	Crest height (m)	Surge (m)		
	5.18	6.22	0.61		10.78
MCEVD (GUA)	6.53	7.84	0.61		12.40

MULTI-SENSING NODE ARCHITECTURE FOR WATER QUALITY MONITORING

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Abstract- This work presents a multi-sensing node architecture designed and implemented for water quality assessment. The sensing channels of each measurement node include temperature, conductivity and turbidity measuring data. Particular design of the sensing devices, software implementation on the base station, as so as the periodic calibration of the sensors followed by upgrading of voltage to water quality conversion algorithms, through the data stored on a SDcard, assures high measurement accuracy. Using a 2X RS232 to Ethernet converter and a Ethernet bridge, the data from the WQ measurement node and the node localization, delivered by a GPS unit, is wirelessly transmitted to a base station. Embedded software was developed for the PIC18F4520 microcontroller using the MPLAB C Compiler for 18MCU Microchip implements data acquisition, SD card data reading, primary processing, and data communication. Additional LabVIEW software implemented on the base station level includes data communication, data logging and graphical representation of the WQ data from selected monitoring nodes.

Keywords: water quality monitoring, embedded systems, conductivity, turbidity, temperature

INTRODUCTION

Water is essential to human life and health, as well, to ecosystem preservation. Water quality (WQ) is commonly defined by its physical, chemical, biological and aesthetic (appearance and smell) characteristics [1].

To perform water quality assessment, different parameters are measured using field measuring systems with multi-channel sensing capabilities such Quanta Hydrolab and Seabird SBE 25 that are expensive equipments with proprietary software for remote control and data management. The main measured parameters are usually pH, conductivity, temperature, dissolved oxygen and turbidity, but different low cost measurement solutions, supported by friendly software, are reported by different authors [2][3]. Different architectures regarding distributed systems for water quality assessment were implemented by the authors and significant results were published during the last 10 years [4][5].

Considering the importance of the WQ parameters, the aim to develop water quality sensing nodes that are part of the design and implementation of Sado Estuary water quality monitoring network, is an important issue. This paper presents a low cost architecture for a WQ multi-sensing node based on a PIC18F4520 microcontroller and a set of WQ sensors developed in laboratory that associated with electrical conductivity, turbidity and temperature measurement.

MULTI-SENSING NODE ARCHITECTURE

The multi-sensing node architecture was designed to permit the measurement of an extended number of water quality parameters and presented in Figure 1. A low cost microcontroller is used to perform acquisition and digital control tasks associated with temperature sensing channel (TS), conductivity sensing channel (CS) and turbidity sensing channel (TUS). Appropriate conditioning circuits (Tcc, Ccc and TUcc) were developed as part of them receiving controls from the microcontrollers through DIO or PWM. Different communication interfaces of the microcontroller are used to transmit the primary processing data (UART) or to read the WQ conversion coefficients stored on the SDcard memory (SPI).

A. Sensors and Conditioning Circuits

The system sensors are a temperature sensor (TS) based on a NTC thermistor, a two-electrode conductivity sensor (CS), and a modulated four beam infrared (IR) turbidity sensor (TUS) [6]. The conditioning circuit used to convert the temperature variation T of the thermistor into a voltage, V_T, acquired by the acquisition, primary processing and communication unit includes a voltage divider with low tolerance resistors, a voltage follower, a differential amplifiers and an inverter

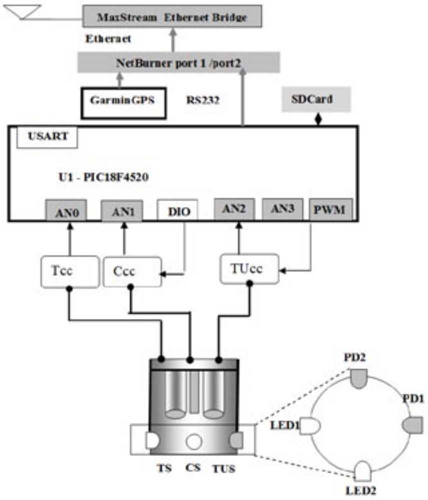

Figure 1. WQ multi-sensing node block diagram (TS-temperature sensor, CS – conductivity sensor, TUS- turbidity sensor, Tcc- temperature conditioning circuit, Ccc – conductivity conditioning circuit, TUcc – turbidity conditioning circuit, Netburner – 2XRS232/Ethernet bridge)

The conductivity conditioning circuit is based on a monolithic integrated circuit function generator XR-2206 that provides the AC excitation signal applied to the conductivity electrodes. The measurement of the conductivity cell impedance was done using different frequencies of the AC excitation signal. Good results were obtained for a frequency around 10 kHz and a 6 Vpp signal amplitude. Considering the conductivity dependence with temperature, a temperature compensation algorithm that uses the voltage values acquired from the temperature (V_T) and conductivity (V_C) measurement channels was implemented at the microcontroller level.

The architecture for the turbidity sensor includes a set of two IR LEDs (LED1 and LED2) and two infrared photodiodes (PD1, PD2) [6]. A pulse-width modulation signal is used for current drivers control to assure appropriate current for better sensitivity of the optical turbidity measurement cell. Thus, by varying the duty cycle of the control signal output by the microcontroller PWM1 ports, and using fc=1Hz low pass filters followed by voltage-to-current converters, excitation currents up to 60mA are obtained, which guarantees a high optical excitation power for low range turbidity measurement values (0-100NTU). When higher values of turbidity are expected the measurement range is automatically changed through the usage of reduced value of duty cycle of the PWM signal meaning low excitation current applied to the IR LEDs. The sets of voltages obtained from PD1 and PD2 for two measurement phases (LED1=on, LED2=off; step2: LED1=off, LED2=on) are used to calculate the TU values by the microcontroller.

B. Microcontroller and Interfaces

The multi-sensing node architecture is based on PIC18F4520 microcontroller that includes a set of three A/D converter channels (AN0, AN1, AN2) with a 10bit resolution. Additionally, microcontroller's digital lines (DIO0) are used to control the CCc, and PWM1 port is used to control the CC_{TU} . Taking into account the nonlinearity of the conductivity measuring channel, a voltage to conductivity conversion algorithm was implemented based on 3rd order polynomial model that was calculated using the experimental characteristics of the conductivity measuring channel $V_C=V_C(CSi)$ [uS/cm]. A. linear temperature compensation $C_T = C_{Tcal}\ (1+\alpha\cdot(T\text{-}Tcal))$ was used to normalize conductivity measurements for a temperature equal to 25 ºC (T current temperature, Tcal reference temperature, usually equal to 25ºC, α -temperature coefficient that is about 0,02 for salt water solutions).

The turbidity calculation is based on acquisition of the V_{11}, V_{21}, V_{12}, V_{22} voltages using the AN2 and AN3 microcontroller analog inputs. The absorbance compensated TU measurement values are given by [7][8]:

where C0TU and C01TU are the values of the coefficients that are obtained in the calibration phase when different formazine standard solutions (e.g. TUS1=20NTU, TUS2=80NTU) are used. The calculated WQ values are transmitted through RS232 communication on the NetBurner SB72-EX low cost, high performance Serial-to-Ethernet converter that receives the information from the GPS module. Using a Wireless Ethernet Bridge from MaxStream [9] the digital values of the WQ parameters are transmitted to the base station. A LabVIEW software implemented by the PC assures data reading, and advanced processing of the WQ values (e.g. temperature compensation and short time data prediction), data storage and a WQ database that can be used to generate dynamical WQ web pages [10].

$$TU = C_0^{TU} + C_{01}^{TU} \cdot \sqrt{\frac{V_{11} \cdot V_{12}}{V_{21} \cdot V_{22}}}$$

RESULTS AND DISCUSSIONS

To obtain the parameters associated with the inverse models of WQ measurement channels that permit the conversion of the acquired voltages into WQ levels (e.g. voltage to temperature conversion, voltage to water conductivity conversion, voltage to turbidity conversion) an experimental work was done. Using a temperature controlled oven, a set of five temperatures were imposed in the 5ºC to 25ºC interval and the linear approximation of temperature measurement channel characteristics were obtained. The inverse modeling of the water conductivity measuring channel was done using a set of conductivity standard solutions from Oakton (CSS1=84uS/cm, CSS2=1413uS/cm, CSS3=2784uS/cm, CSS4=15000uS/cm). The acquired voltages were used to extract the polynomial approximation of $C_{Tcal}=C_{Tcal}(Vc)$ characteristic.

Regarding multi-sensing node evaluation, different tests were performed to verify measurement accuracy taking as reference measurements delivered by a Quanta Hidrolab reference multi-parameters' probe. In this moment the team is working to develop an improved version of Geographic Information System [10] implemented on the base station level that receives data from the implemented multi-sensing node.

IV. Conclusion

A microcontroller based architecture for water quality multi-parameters sensing node was designed and implemented. The temperature, conductivity, and turbidity sensing channels were designed and implemented and different laboratory tests were carried out. The embedded system assures the control and data communication associated with WQ quantities that are transmitted to a PC that performs data processing, data storage and data representation tasks. Through calibration and using appropriate inverse models for the measuring channels characteristics, accurate values of WQ measured quantities were obtained. Elements of system calibration, inverse modeling and base station software are part of the final version of the paper.

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REFERENCES

[1]Water on the web, "Understanding: Water Quality", on-line at: http://wateron-theweb.org/under/waterquality/index.html

[2] A. Charefa , A. Ghaucha, P. Baussandb, M. Martin-Bouyera "Water quality monitoring using a smart sensing system", Elsevier Measurement, vol 28, pp. 219–224, 2000

[3] O. Postolache, P. M. Girão, G.P. Patricio; J.S. Sacramento; P.M. Macedo, J. Dias Pereira, "Distributed Instrumentation and Geographic Information System for Dolphins' Environment Assessment", Proc IEEE International Instrumentation and Technology Conf. - I2MTC, Victoria, Canada, Vol. I, pp. 1777 - 1782, May, 2008.

[4] O. Postolache, J. M. Dias Pereira, P. Girão, "Real-Time Sensing Channel Modelling Based on an FPGA and Real-Time Controller", Proc IEEE Instrumentation and Measurement Technology Conf., Sorrento, Italy, Vol. Vol I, pp. 557 - 562, May, 2006.

[5] O. Postolache, P. Girão, J. M. Dias Pereira, H. Ramos, "Intelligent Processing of the Dynamic Response of Sensors for Water Quality Monitoring",Trans. on Systems, Signals and Devices, Vol. 3, No. 4, pp. 539 - 550, April, 2008.

[6] O. Postolache, P. Girão, J. M. Dias Pereira, H. G. Ramos, "Multibeam Optical System and Neural Processing for Turbidity Measurement", IEEE Sensors Journal, Vol. 7, No. 5, pp. 677 - 684, May, 2007.

[7] J.M. Dias Pereira, O. Postolache, P. Silva Girão, Helena Ramos, "Colored Light-to-Voltage Converters Based Absorbance Meter", International Scientific Journal of Computing, Vol.2, Issue 1, pp. 58-64, 2003.

[8] O. Postolache, P. Silva Girão, J.M. Dias Pereira, H.G. Ramos, "An IR Turbidity Sensor: Design and Application", IEEE Instrumentation and Measurement Technology Conference (IMTC/2002), pp. 535-539, Anchorage, AK, EUA, May, 2002.

[9] http://www.digi.com/products/wireless/xstream.jsp#docs

[10] O. Postolache, P. Girão, J.A. Apolonia; N.B. Beirante; P.M. Macedo, J. Dias Pereira, "Dolphins' Environment Assessment and Knowledge Management Using a Distributed Instrumentation and Geographic Information System", ProcIMEKO TC4 Symp., Florence, Italy, Vol. I, pp. 454 - 459, September, 2008.