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Hard- and Software solutions for autonomous maritime systems

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ABSTRACT

One important task in marine research is the investigation of processes of particle exchange and transport using filtration sampler, bottom water sampler, sediment traps or other equipment. In this paper, we describe a modular hardware solution (microcontroller, flash-memory, analog-to-digital converter, system interface) together with a user-friendly software which is suitable for event-referred control of systems which have to work autonomously for longer periods.

Keywords: Online monitoring, Applications of Sensors

1. Introduction

Autonomously working systems have already been used in maritime research in different fields of application for decades. Often, it is not possible to keep a permanent connection with a cable. This stems from the depth of missions up to 6000 meters, difficult reachable locations or mission periods of several months. Generally, the power supply of such systems can be guaranteed with accumulators only. Alternative energy sources such as wind generators or solar cells are not usable because of the depth of missions. Therefore, the design concepts for such systems should include a minimization of the power demand for each single system component.

Environmental investigations, such as water pollution, require a controlled extraction of filtrates during long periods [1]. Generally, autonomously operating filtration samplers are used for this purpose. The number of filter places, however, is always limited for such systems. That is why, intelligent principles of selection have to be specified for the filtration rules based on real-time hydrological measuring data at regular time intervals.

2. Event controlled system

Generally, autonomous measuring systems in marine research operate at equally spaced time steps. That means, after a predetermined starting date, measured data are collected and stored or passed on to the operator in certain time intervals.

It was our main intent to develop a new energy-saving control unit for autonomously measuring systems which drive peripheral devices in dependence on sensor data only in the case of defined events.

The real events are identified on the basis of sensor data and predefined decision rules [2]. The water exchange between the North Sea and the Baltic Sea correlating with the variation of salinity is only one example. During irregular time intervals, salt-bearing deep water comes into the Baltic Sea. This event is very important for the whole balance of this semi-enclosed brackish water ecosystem. Vice versa, predominantly surface water with a noticeable lower salt concentration flows back into the North Sea.

The above mentioned inflow of salt water is characterized by extreme values, also called events in this context. Such inflows take often only a few days or weeks. If the times for sampling are predetermined and equally spaced for each of the individual filtration places, many of these events would be invisible resulting in many irrelevant filtrates.

It is highly estimated that relevant physical, chemical, or biological hydrodynamic processes are not recognizable when time-triggered autonomous systems are being used.

An event controlled sampling system is able to respond to variations of considered parameters with starting specific measuring and sampling procedures. Therefore, the risk of missing an event and the power demand of such a sampling system is substantially being reduced.

3. Hardware solutions

Figure 1 shows the block diagram of a filtration sampler. The predominant energy consumption is shown in the dark flow chart. Primarily, the main energy consumers are the actuators as the pump and the valves, the sensors including the current meter and the radio communication. The electrical current demand could be reduced on the MSP 430 circuit board and on the peripheral interface board to less than 3 mA by using the ultra-low power microcontroller MSP 430 as well as by consequential turning-off of all unnecessary electronic devices [3]. This state will be forced by the microcontroller during the breaks between the measuring intervals.

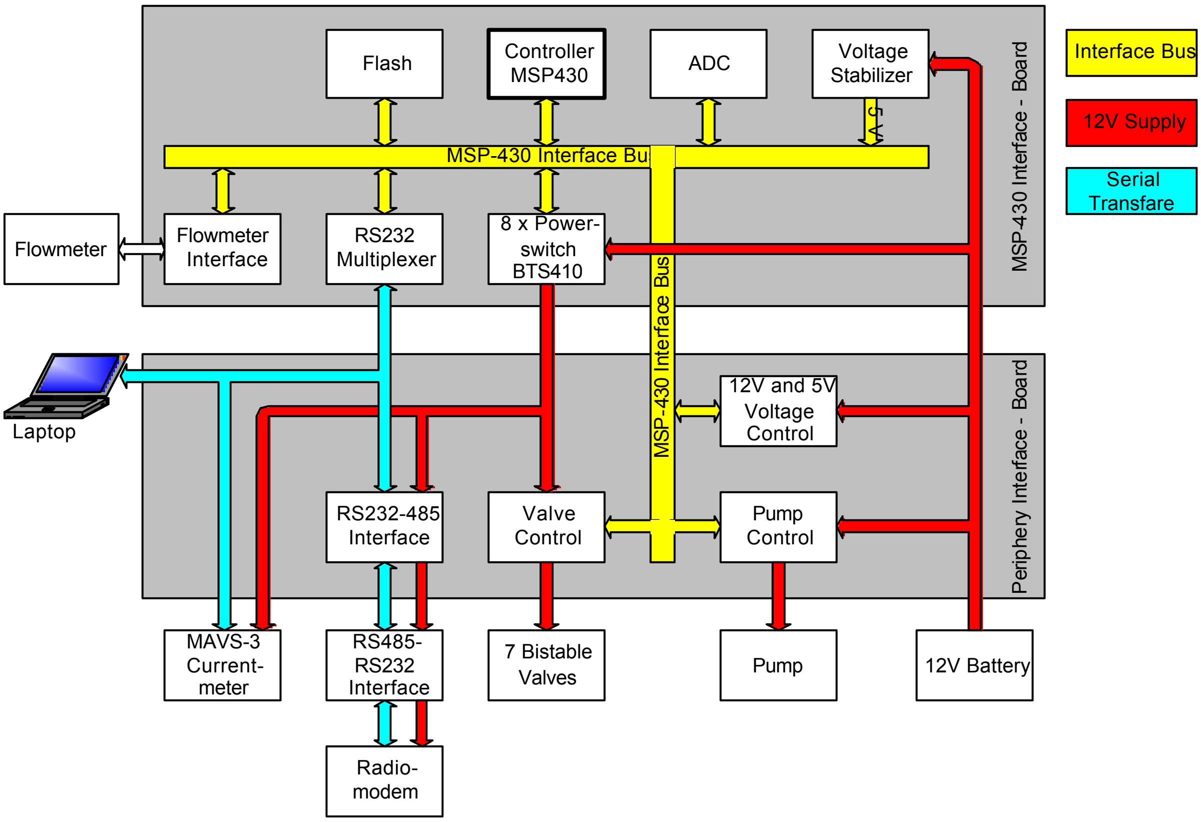

Figure 1: Block diagram of the filtration sampler

In dependence on the measuring interval chosen, it amounts on the average to approximately 90 percent of the whole application time. The activation of the microcontroller proceeds with a basic-timer routine. The Texas Instruments MSP430 series is designed to be battery operated for an extended application lifetime. With the 16-bit RISC architecture, 16 integrated registers on the CPU, and the constant generator, the MSP430 achieves maximum code efficiency. The microcontroller decides about the activation of the actuators by means of commands transmitted over the radio link or based on the sensor data. Each of the peripheral facilities is powered up with BTS 410 elements (Infineon Technologies AG). The BTS 410 is equipped with a status feedback, which is advantageous for the programming of error treatment routines.

The pump can be operated preferably at a different power level if the duration of pump operation is irrelevant. Therefore, the static and dynamic components of the power loss are reduced so far that nearly no heating of the power-FETs occurs.

Power-saving, bistable valves of the Italian company RPE (type 6301) are used for triggering the filter places. The valves are triggered with a short voltage pulse and they keep their state after the shutoff of the control voltage as well. A current consumtion takes place only during the changeover of the valves. The bistable switch-over valve needs a 12 V voltage pulse for 60 milliseconds for opening. The valve will be closed with a pulse of opposite polarity. The electronics are suitable for the triggering of eight valves, but an upgrade to more valves is possible without problems.

4. Radio communication

The formulation of a current saving concept is one important task prior to the implementation of the radio communication link. The choice of the radio modem depends on the conditions in the operational area of the filtration sampler. In the following, we describe our concept of a radio link using the 434 MHz band.

The radio modem is adapted for the license-free digital radio data transmission. The modem has a transmitting power of 8 mW on the 434 MHz band. In open space, the range is approximately 1000 meters. The current input is specified with <55 mA for the transmission mode and with <40 mA for the receiving mode. The sett up of a radio link can be accomplished only bilaterally. The GSM cell-phone, located on the measuring mast, is called via the radio modem from the PC located in the remote laboratory. A RS232 interface connects both, the GSM cell-phone and the radio modem on the measuring mast. The GSM cell-phone has to be configured for automatic call acceptance. A transparent connection between the remote station and the radio modem exists if the radio link to the GSM cell-phone is established.

The computer of the remote station sends the control codes for selecting the radio channel and for changing the radio modem to the transparent mode. The radio modem, which is fixed at the buoy of the filtration sampler, will also be activated and switched to the transparent mode by the MSP 430. The result is an end-to-end link between the remote station and the filtration sampler. Figure 2 shows a schematic view of the radio communication. A limitation on a time window for establishing the first contact is mandatory because of the current consumption of 40 mA during the receiving operation. The filtration sampler activates the radio modem, for instance, every hour for 5 minutes waiting for incoming commands.

The radio modem (DFM 10N) is suitable for transmitting and receiving of short data blocks. Compared with a GSM modem (e.g. the A20, Siemens AG) the power consumption is much lower for the transmission mode. A GSM modem should be used, however, for the employment in larger distances to a receiving station.

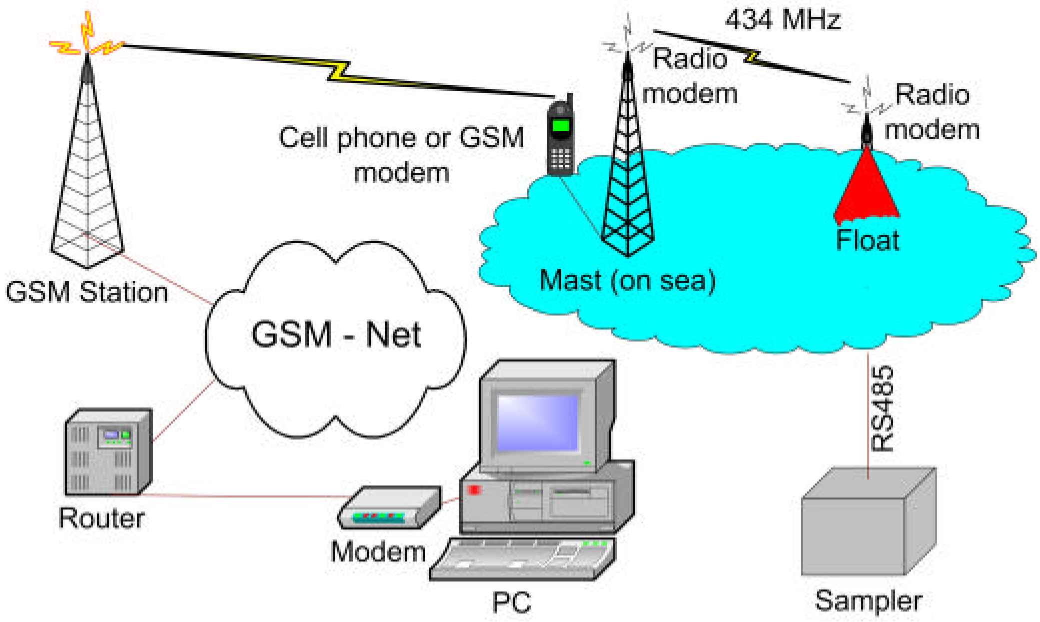

Figure 2: Schematic view of the remote controlled system

5. Alternative energy sources

The maximum length of the application of autonomous maritime systems is determined by the capacity of the energy source. Furthermore, the measuring dynamics, the number and the kind of sensors, as well as the duration of the actuators operation, depend on the available energy.
Solar radiation or wind power can be used on swimming systems. Subsurface systems are supplied nearly exclusively with accumulators.

The reduction of the power demand of maritime systems is one precondition for the use of different alternative energy sources. A continuous energy flow is provided by sources such as wave energy, which is used in OWC buoys [4] or in piezoelectrical transducer systems [5]. However, large capacities are not available in most cases. The most frequent proposed systems transform the movements of a buoy into useful energy. This buoy drags in phase with the rhythmic waves motion on a rope, which is connected with a generator. But, a low water depth is the condition to run out the buoy.

OWC-systems (Oscillating Water Column) have been used successfully for decades as light buoys. The Oscillating Water Column generates electricity in a two-step process. As a wave enters the column, it forces the air in the column up the closed column past a turbine and increases the pressure within the column. As the wave retreats, the air is drawn back past the turbine due to the reduced air pressure on the ocean side of turbine.

A thermoelectric generator is described in ref. [6]. Electric energy will be produced by means of temperature differences. Nowadays, the power generation on the basis of linear generators is in the test stage. The conversion of the movements of a buoy into electric energy takes place through linear generators [7].

The results from short term tests were promising.

Alternative energy sources provide enough energy to operate in event driven sleep mode.

6. Conclusion

In this paper, we presented a concept for the development of an autonomously working system for marine underwater applications which has a significant low power demand and is equipped with an intelligent control unit.

The implementation of an ultra-low-power micro-controller, in combination with several other procedures of power savings, is leading to a doubling of mission time on condition that the battery capacity is the same. The necessary sensors and electrical actuators are supervised by the micro-controllers software, particularly, with regard to a minimum power demand. The use of bistable valves contributes to further savings.

The entire development was based on the principles of modularity of all hardware and software components. That is why, the microprocessor controlled system can be easily adapted to other combinations of sensors and actuators for different fields of application, especially in systems where a low power demand is essential.

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