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Underwater Navigation and Communication: A Novel GPS/GSM Diving Computer

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Abstract:

An important issue for divers is orientation. Communication to the outer world might be beneficial, too. The present paper details a mixed gas diving computer, which is extended by navigation and communication assistance. A prototype was build up consisting of a microcontroller, a digital pressure sensor, a memory chip, a graphical display for visualization and a GPS/GSM unit. The dive computer unit uses the Buehlmann ZHL-16C (with Gradient Factors) decompression algorithm to calculate decompression schedules with arbitrary gas mixes. Navigation and communication assistance is provided by a GPS/GSM unit integrated in a surface floating buoy that is connected to the diving computer via a cable on a reel. First tests under real conditions were successfully carried out.

Introduction:

One important issue for divers is orientation. Till now divers use a watch, depth gauge and compass to navigate, which is especially important if visual orientation points are absent (caused by e.g. bad visibility or no contact to the sea bottom). Recreational divers have to navigate, if they want to dive individually without dive guide. Especially for beginners, additional navigation support could be a benefit. Special forces are often dependent on precise navigation to fulfil their mission – which is difficult especially in the presence of current.

The opportunity to communicate with the outer world during a dive might be beneficial too. The possibility of sending a SMS could be useful, if unexpected problems occur during a dive (like lost of decompression gas, lost of the diving boat, sudden current, diving accident, etc.).

The present paper describes a new kind of diving computer, which provides navigation and communication assistance. The main idea for this novel underwater navigation and communication device is to extend a regular diving computer with a buoy-system, which includes GPS (Global Positioning System) and GSM (Global System for Mobile Communications).

Methods - Hardware:

Core component of the present system is the handheld diving computer which incorporates a low power 8-Bit RISC microprocessor [Atmega644p, Atmel] with the following specifications:

- 64 kbytes Flash Program Memory
- 4 kbyte SRAM
- 2 kbyte EEPROM
- 8 MIPS @ 8 MHz

For depth measurement, a digital 15-bit pressure sensor is integrated in the design [MS5541B, Intersema]. It is specified for a maximum pressure of 14 bar. A 128x64 matrix display [EA DOG-M, Electronic Assemby] is used to visualize all dive computer specific parameters, plus distance and heading to a preset destination. The dive profile is continuously tracked and stored into an external 32 Mbit memory chip [AT25DF321, Atmel], which allows continuous recording for 190h (by a sampling interval of 1s). To provide GPS and GSM functionality in one small device the combined GSM/GPS module GM862 from Telit was chosen and is integrated in a buoy-system. Communication between dive computer unit and buoy-system is done via serial communication. A 3-wire cable (RXD, TXD, Mass) establishes the physical connection. Special shielding of the wire is not necessary, because of its underwater application. The communication speed is 9600 BAUD. Additionally an analogue pressure sensor [Poseidon, Sweden] is mounted to measure the tank pressure via the analog to digital converter of the microcontroller.

The overall low power consumption allows powering the whole diving computer via a single 1.5V AA battery together with a step up converter. The buoy-system is powered by a LiIon cell phone battery (1800mAh). Figure 1a gives an outline of the device.

Methods – Software:

The firmware of the device is developed in the programming language C. As Integrated Development Environment (IDE) the IAR Embedded Workbench [IAR Systems] was chosen. It is a set of development tools for building and debugging embedded applications using assembler, C and C++ in Windows 9x/NT/2000/XP/Vista environments.

Continuous tracking of the diving profile and the calculation of decompression schedules in realtime with arbitrary gas mixes (nitrogen and helium) is very time intensive on a low power 8-bit microcontroller without floating point support. Thus a preemptive scheduling algorithm with fixed priorities is implemented, which controls dive profile tracking, decompression schedule calculation and GPS/GSM communication quasi in parallel.

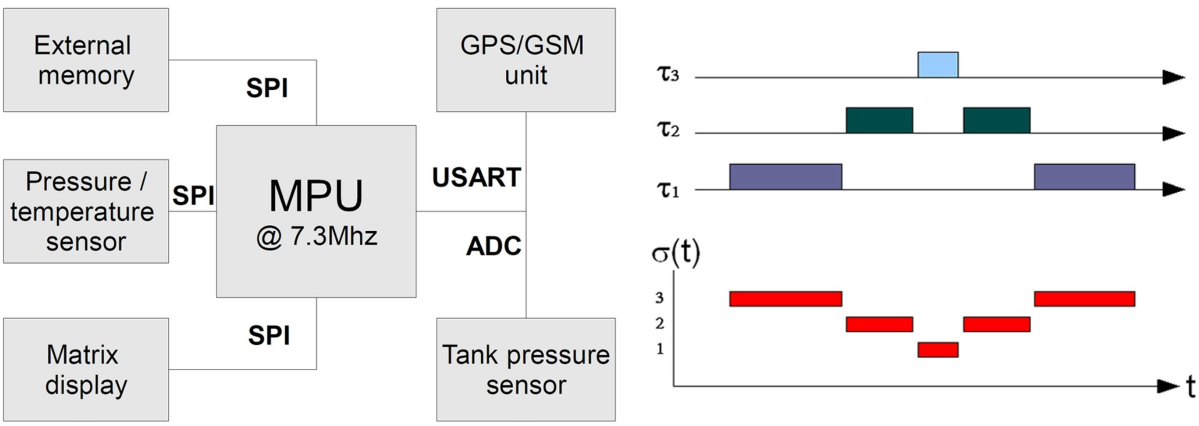

Figure 1 a) Hardware diagram **b) Scheduling algorithm**

To achieve a precise timing of dive profiling, the tissue saturation computation of the Buehlmann ZHL-16C (with Gradient Factors) [1][2][3][4] decompression algorithm is interrupt controlled. The internal timer of the Atmega644p is triggered every 250ms to create an interrupt where tissue gas loadings are updated (Figure 1b Task $\tau 2$ with priority 2). The decompression schedule is calculated in the main loop (Figure 1b Task $\tau 1$ with priority 3). Since it is calculated using a copy of the tissue saturation and the tissue saturation is updated continuously during the interrupt, the computation time to calculate a decompression schedule is less important. GPS/GSM communication is controlled by a background process, which triggers the GPS/GSM jobs. USART communication to fulfill arbitrary GPS/GSM jobs are interrupt controlled, too. To prevent that no data packet gets lost during USART communication, the USART interrupt has a higher priority than the timer interrupt (Figure 1b Task $\tau 3$ with priority 1).

Results:

A first prototype was build up (see figure 2a). The diving computer is housed in an aluminum case, filled up with silicon gel. The buoy-system is housed in a proprietary Drybox (specified to 50m). The Drybox has an inner size of 5cm x 10cm. Diving Computer and buoy-system are connected to each other via a 40m long 3-wire cable and a waterproof IP68 connector [Fisher Connectors]. If no buoy-system is required, it can simply be plugged off. To ensure easy recharging of the buoy-system battery, a charging connector is placed at the bottom side of the buoy-system.

The final system is small and handy. The diving computer unit has a size of a regular diving computer and can be carried on the wrist. The cable between diving computer and buoy-system has a diameter of 3mm and thus fits on every reel. The buoy-system can be stored in the pocket of a regular BC, if it is not used.

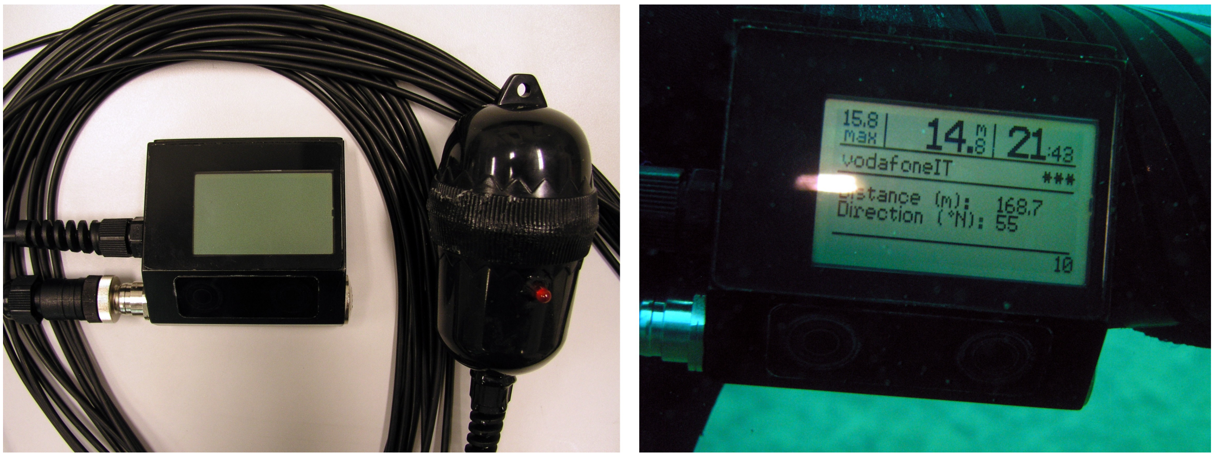

Figure 2 a) Prototype **b) Screenshot of the navigation screen**

The diving computer includes the Buehlmann ZHL-16C decompression algorithm for nitrogen and helium, so that every arbitrary gas mixture as travel, bottom and decompression gas can be used. GPS coordinates are updated every 2 seconds. Distance and angel to arbitrary setpoints are calculated on the fly (see figure 2b) [5][6]. Predefined SMS can be sent to preset phone numbers. The configuration of all predefinitions is done via serial interface in a PC-software.

First floating and communication tests were carried out in the 10.5m deep research pool at Divesystem [Massima Marittima, Italy]. Further test dives under real conditions were successfully done at the lovely Tuscan seaside in Italy. Extensive field tests will be done by the state police of Italy in August 2009.

Discussion:

GPS and GSM do not work underwater. So, if a diver wants to use GPS/GSM, it is necessary to mount the unit on a buoy, which is floating on surface. In some countries it is mandatory to drag a buoy behind the diver. Thus for these divers it makes no difference, if they carry a buoy with or without 'intelligence'.

Always carrying a buoy during a dive is for some divers not preferential (if it is not mandatory), because it might limit the scope of the diver (f.i. during wreck dives). That is why the above described buoy-system is designed as small as possible to fit into the pocket of the BC. The system can be set, only if it is required. It has positive buoyancy and ascents to surface without any foreign help. Furthermore it can be clipped on the decompression buoy during the ascent.

For sure the SMS functionality will be used to send fun SMS to jealous friends to tell them about the current dive, but it might also increase the safety during a dive, because in crucial situations rescue assistance can be initiated earlier.

Conclusion:

The introduced prototype combines a mix-gas diving computer with a GPS driven navigation system and a GSM. It allows navigation and GSM communication underwater. A buoy-system can be set, whenever GPS/GSM is necessary or it can be continuously dragged behind the diver (f.i. in a country, where a buoy is mandatory anyway). Several test dives were successfully conducted in the Mediterranean sea.

Acknowledgement:

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Preferences:

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