Underwater Glider Controlled System Based On PSoC5LP

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Abstract- *Underwater gliders are class of autonomous Underwater vehicles (AUVs) generally used for oceanographic data collection. Propelling force for the underwater glider is generated by change in buoyancy which makes the glider to follow a saw-tooth pattern of motion. This concept is efficient and cost effective strategy for automated oceanographic data collection and analysis. The aim is to provide a proper control over the glider control mechanisms consisting of buoyancy variation, data storage from sensors and periodic transmission of data to the base station.*

Keywords- Underwater glider, embedded platform, Programmable System on Chip, Buoyancy engine.

I. INTRODUCTION

Random fluctuations in the Indian Ocean Region (IOR) basically affects the research in specific locations which hinders the analysis of that portion of ocean. That is why conventional propellers are not used by Autonomous Underwater Vehicles (AUVs) [1]. Self noise is minimised due to this. Their basic characteristics include small size, long endurance, low speed and very low cost. This way it becomes reachable to even the common man intensifying the research in different areas. Such a design and deployment of gliders with proper set of sensors within itself will be an effective way of improving sonar performance of military also. Basic purpose of glider is to acquire data using required sensors, power supply module, processors, system controllers, memory for storage of information acquired. This paper is focused on electronics, onboard controller logic and hardware including control mechanisms.

II. REVIEW OF PREVIOUS WORK

In the year 2004, the four important members of family were deployable: Slocum battery and Thermal by Webb Research Inc, Falmouth, USA, Spray glider from the Scripps Institution of Oceanography, and Sea glider made by the University of Washington. Different techniques are used by gliders to vary buoyancy and to convert vertical movements into horizontal movement resulting in a sawtooth motion pattern. Glider completes various dive cycles before ascending to the surface so as to transfer data via satellite link. Dive cycle is basically the sinking of glider to a defined path and then rising to another depth in the water column. They can be deployed by a small crew of two or three persons. Slocum thermal glider use a hydraulic buoyancy engines with battery powered pumps or pistons. Slocum Thermal is sensitive to the thermal gradient of ocean and so changes the overall state of medium from liquid to solid and vice versa accordingly so as to change its displacement. But with this comes a limitation to its operation areas.

The sea glider makes use of the Onset Computer Corporation's TT8 controller as the main electrical component. A Motorola microcontroller called MC68332 along with a 12-bit A/D converter and power conditioning circuitry on a small printed circuit board is utilised by TT8 controller [2]. Scientific Instrumentation on sea glider is conductivity-temperature-depth (CTD) from Sea bird electronics [3]. Iridium satellite communication system is used by sea glider for transfer of data to the base station. In spray glider the Onset TT8 controller and associated electronics subsystems are utilised for buoyancy control, interrogation of scientific sensors, processing and storing data, navigation and satellite communication [4]. All the extra sensors include fluorometers, dissolved oxygen meter, turbidity and altimeter.

III. DEMONSTRATION PROTOTYPE OF UNDERWATER GLIDER

A. Buoyancy Engine

The existing literature gave rise to three options for a variable buoyancy engine.

- Piston operated tanks
- Hydraulic pump with external bladder
- Chemical propulsion

For the sake of simplicity of demonstration buoyancy engine with piston operated tanks has been selected for prototype stage. Rack and pinion mechanism is utilised for the operation of pistons of the tank. All this is driven by an actuator high power to weight ratio. The force required for charging and discharging of buoyancy chamber is given by

$$\text{Force Applied} = \rho g h A + F$$

Where, ρ= Density of water
g=Gravitational force
h=Depth of operation
A=Area
F=Force required to overcome the friction of the inner wall of the buoyancy chamber.

The actuator torque requirement can be determined from the calculation of force required to be applied on the piston in order to charge and discharge the buoyancy tanks. An efficient DC motor was used to simulate the actuation of buoyancy engine in the prototyping stage.

B. Sensor Package

Sensor Package selection is dependent one application of underwater glider. Conductivity-temperature-depth (CTD) package is basic sensor on glider. Pressure sensor output is utilised for controlling vehicle as well as labelling the depth at which temperature and electrical conductivity are to be measured. Acetal housed miniCTD profiler from Valeport was found to be suitable for utilisation with regard to weight, dimensions and ease to interface with the microcontroller unit. Slightly less costing sensors are utilised namely temperature (LM35) and digital pressure sensor (BMP085), along with the conditioning circuitry which is used for data collection.

C. Navigation and Communication system

At the point of surfacing of vehicle during the saw tooth evolution navigation fixes from the underwater glider to the remote underwater glider base station are conducted. The inertial navigation system (INS) aided by GPS, is found to be suitable for the glider application. The weight, accuracy, power consumption and the available external interfaces need to be considered for selecting a suitable navigation system. Xigbee PRO module, operating in the ISM band (2.4 GHz) and with data rate of 250kbps is used as the communication module for transferring the stored sensor data to base station. Having outdoor line of sight coverage of 2 miles and indoor coverage of 200m with a transmission power of 63mW it is powered by 2.6 to 3.3 V DC with transmit and receive current of 205mA and 47mA respectively.

D. Embedded Hardware

Low power, small size and versatility allowing integration of current and future sensors is the primary requirement for an underwater glider embedded system. A microcontroller with submilliampere active and sleep modes are used. Reduction of circuit board size is also required. A large number of serial communication channels as well as analog and digital channels are required for sensor integration.

The Programmable System on Chip (PSoC5LP) from Cypress Semiconductors was selected as the microcontroller unit for the glider, with a 32 bit ARM cortex M3 CPU core [5]. The presence of programmable analog and digital blocks is essential for integration with peripheral devices. Memory requirements are accomplished by 256KB of flash memory, 64 KB of SRAM and an external SD card of 1 GB for sensor data storage. It has a 12-bit Delta sigma A/D converter and a 20-bit Successive Approximation Rate (SAR) A/D converter. The power consumption in active and sleep modes are 3.1 mA and 2 µA respectively. There are 62 GPIOs (General Purpose Input Output) that can be configured for analog or digital input/output.

IV. EMBEDDED SYSTEM PROGRAMMING

The main control functions of embedded system are as follows:

- Periodic charging / discharging of buoyancy tanks with water for varying buoyancy by providing control signal to buoyancy engine.
- Collection and storage of data from onboard sensors as the glider follows the “saw-tooth” pattern.
- Data collected by the sensors is required to be transmitted to the base station for analysis.

The IDE (Integrated Development Environment) called PSoC Creator 4.3 provides the hardware and application firmware design for the embedded platform. A schematic of hardware design is created by the analog and digital component catalog. While using software the configuration of analog and digital components is done using application programming interface**.** Each programmable component in the component catalogue includes the set of related API libraries. After completion of hardware design, the firmware is written, compiled and debugged by the IDE.

A . Buoyancy Variation

The buoyancy chamber is periodically charged and discharged so as to achieve negative and positive buoyancy respectively. Depth of operation is the key deciding the time interval between charging and discharging. The recorded data samples are used as sequential logic for charging and discharging cycles. The piston operated buoyancy engine is driven by the actuator of high power to weight ratio. The DC motor used in place of actuator is interfaced to the port of the microcontroller unit PSoC5LP through a voltage regulation circuitry. PWM (Pulse Width Modulation) control voltage for actuator operation is provided by PSoC5LP. PSoC Creator (IDE) configures the PWM and peripheral ports for actuators. The PWM component is configured for 8-bit resolution and set up in dual mode of operation. The dual mode provides actuator operation in clockwise and counter clockwise direction. The periodic charging and discharging of buoyancy chamber can be done with appropriate time delay of PWM. API (Application Programming Interface) provides the software control for charging and discharging of buoyancy chamber.

B . Collection and Storage of Sensor Data

The amount of storage required is determined by the maximum depth of operation, data size and polling rate. Data packet basically consists of temperature and pressure sensor data along with time stamp. Sensor data is converted from float to character data type before storage. Formatting of SD card is done using API before storing the data packets. With clock frequency of 4000 KHz the SD card is mounted on the Arduino shield and interfaced to PSoC5LP through Serial Peripheral interface (SPI). Separate files are generated for each dive cycle. In order to conserve power smaller fragments of large data files are made and retransmission is avoided if errors are detected. After completion of each dive cycle existing file is closed and new file is opened for data storage.

C . Communication

For communication purpose ESP8266 is used which is serial WiFi module. Here, it is used as adapter allowing to send the data stored to target computer upon which analysis of the data is done. It has high degree of on-chip integration, which includes the antenna switch, power management converters and requires minimal external circuitry. This method reduces the load of memory requirement as the stored data is being continuously transmitted to target computer. Using various commands ESP8266 is interfaced with required hardware so as to display results or data. UART is used to connect the transmitter and receiver system for communication.

V. CONCLUSION

The embedded platform for underwater glider prototype was implemented utilizing the programmable system on chip (PSoC5LP). Different actuators are used for controlling the orientation of glider system. Motors are controlled using PWM control. The actuators successfully maintained the control of buoyancy engine and moving mass mechanism. Temperature and pressure sensors sense the inputs and data is stored, transmitted using ESP8266 WiFi module. This basic implementation has brought out the platform for more advanced version of underwater glider control system.

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