

Thruster Control, Power Management and Mechanical Design of Autonomous Surface Vehicle for Coastal Ocean

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ABSTRACT: Autonomous Surface Vehicles (ASV) are vehicles that operate on the surface of the water without a human in order to get multiple oceanic property details. ASVs are valuable in oceanographic domain, as they are more capable than moored or drifting weather buoys, but far cheaper. In the project, It has been configured an ASV having two hulls and two thrusters which will move at a certain speed through the surface of the water and it will take turn depending upon the speed variations of the thrusters. The Arduino Uno as the control kit has been used, and programmed accordingly in order to actuate the thrusters. In this project, two types of batteries are used. Batteries, either primary or secondary, are by far the most common choice of energy storage for past and present ASVs. In the power management section, several DC-DC converters, N-MOSFET, Gate Triggering Circuit has been used. In eagle board the packaging has done and formed a board which will be having the Arduino embedded on it with the other elements.

KEYWORDS: ASV, Arduino Uno, Eagle Board, Solidworks Software, Power Management System, Battery Potential.

I. INTRODUCTION

ASVs can range in complexity but must include four main elements: a body (hull), a propulsion system, a navigation system, and a data collection and transmission system. There is no standard that regulates autonomous surface vehicles and these vessels differ greatly in appearance and functionality depending on the production of the unit and its intended function. ASVs are a relatively new technology and have a brief history. Early ASVs were designed mostly for educational use. Further advancement of ASVs has been due to the rapid progression of technology. For example, Global Positioning System Receivers (GPSR) have become more compact, affordable, and easily available. Today, most ASVs exist as prototypes being developed by private interest groups and are not being applied to perform routine or standardized tasks. There exists at least one company, Liquid Robotics, which markets its ASVs to the commercial market. Submersible vehicle related concepts are not an unfamiliar idea. David Bushnell and his brother, Ezra created "Turtle", the first American submarine which was built at Say-brook, Connecticut in 1775. The Turtle was a little egg-shaped wooden submarine held together by iron straps. Turtle bobbed like a cork in rough surface winds and seas even though she was lead weighted at the bottom. With time, fundamental concepts become clearer and operational experience increased, preferred types of ASVs will undoubtedly be identified.

II. LITERATURE SURVEY

The concept of a submersible vehicle is not a new idea. The first American submarine was called "Turtle." It was built at Saybrook, Connecticut in 1775 by David Bushnell and his brother, Ezra. The Turtle was a little egg-shaped wooden submarine held together by iron straps. Turtle bobbed like a cork in rough surface winds and seas even though she was lead weighted at the bottom. In this hand and foot-operated contraption, one person could descend by operating a valve to admit water into the ballast tank and ascend with the use of pumps to eject the water. Two flap-type air vents at the top opened when the hatch was clear of water and closed when it was as not. The air supply lasted only 30 minutes.

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The Turtle's first engagement, which took place in New York Harbor in 1776, was also the first naval battle in history involving a submarine. (Author: Bishop, 2004).

A major client base for ASV technology may include coastal resorts and businesses that could be affected by an oil spill. Such a disaster can put a halt to income for coastal businesses, and preparation is necessary for the survival of these businesses. Oil mapping data is also valuable to businesses so that they can get reimbursed from the responsible oil company for damage caused by the spill. ISE has taken this philosophy one step further by constructing a web-based tool that allows a potential user to design a specific ASV to meet his/her needs. As operational experience increases, preferred types of ASVs will undoubtedly be identified. The only trend that can be seen now is the two paths that the marketplace has established. The first is the development of small, low cost ASVs. It is envisioned that these systems can eventually be used in groups of cooperating vehicles.

III. METHODOLOGY

An ASV having two hulls and two thrusters has been configured which will move at a certain speed through the surface of the water and it will take turn depending upon the speed variations of the thrusters. The objective was to create an oceanic platform which will send us all the sensor data accordingly in order to follow up the ocean characteristics. It is surface vehicle, not an underwater vehicle. Among the two hulls, one will have the batteries and another will carry the electronics components. Two thrusters are used which generate enough thrust, so that the ASV moves and changes its orientation without fins. The ground work was to test all the peripherals and selecting the right component accordingly.

The hulls are made of aluminum. The next target was to design the ASV. Keeping many considerations in mind, a design has been developed which fill fit under the need list. A PCB board has been designed, through which all the electronics working module comes under a roof. A several components like DC-DC converters, MOS- FETs has been used as a part of the requirements. Two of the SeaBotix thrusters has played an important role in order to move the ASV and it has been controlled using the Arduino Uno.

The required code for actuating the thrusters which are related to hardware PWM has been modified. Speed variation of the two motors took place as these ASV has no fins in it. So, by varying the speed of the thrusters the orientation of the autonomous surface vehicle has been changed. Four of the lead acid batteries and six of the secondary lithium ion batteries has been used. While computing the schematic diagram, the VICOR DC-DC Converter libraries was not there in the EAGLE Board library section. So, it has been designed and put that under consideration.

IV. EXPERIMENTAL WORK

Energy is a key issue for long endurance autonomous surface vehicles (ASVs). Mission duration, speed through the water and sensor and payload capabilities are constrained by the energy available, which in turn is governed by the characteristics of the energy source or sources, the mass and volume that the vehicle designer can devote to the energy system and the details of how the weight of the energy system is countered with buoyancy. Two types of the batteries are used. Batteries, either primary or secondary, are by far the most common choice of energy storage for past and present ASVs. The primary battery is the lead acid batteries and the lithium ion batteries are the secondary storage batteries. Depending upon their discharging characteristics, it has been notified that the primary lead acid batteries take around three hours to drop down from 12V to 6V and the secondary batteries can be used for approximately one hour.

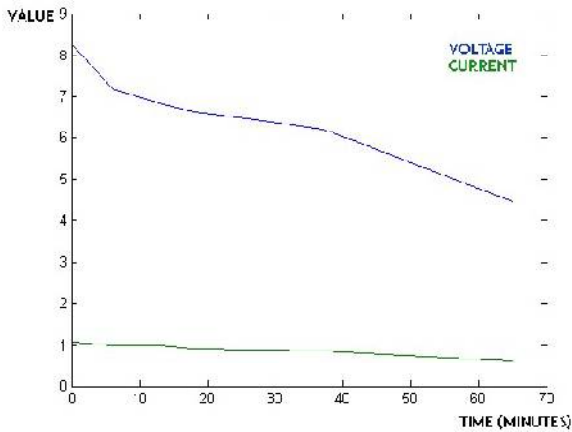


Fig.1 Lithium ion Battery Discharging Graph

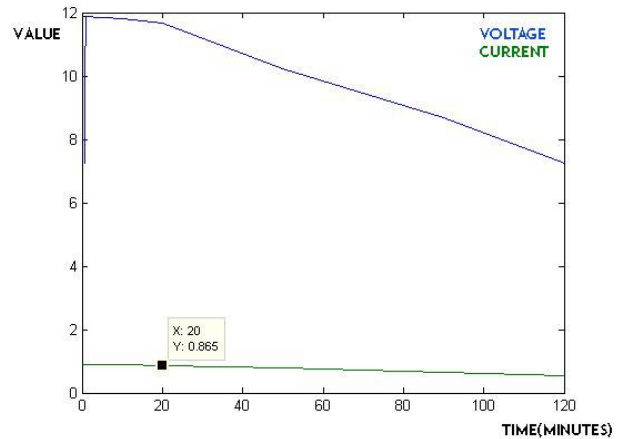


Fig. 2 Lead Acid Battery Discharging Graph

The SeaBotix thrusters are the advantageous choice in ASV/ROV projects. These thrusters will get connected with the motor driver circuit which will drive these at a different speed and in different orientation depending upon the demand. This motor driver circuit is connected to the thrusters through the red part and along with that it will be having 5 input pins. The Arduino UNO is used as the control kit and coding has been done in order to control the thrusters. Using serial monitor window, the command can be sent and depending upon it, the thrusters will actuate in all possible combinations. Actuating one thruster keeping the other one off or vice versa or keeping both the thrusters on or off can be done. The orientation and speed of the thrusters has been achieved separately. The speed is controlled using Hardware PWM. The Arduino's programming language makes PWM easy to use; simply call `analogWrite(pin, dutyCycle)`, where `dutyCycle` is a value from 0 to 255, and `pin` is one of the PWM pins (3, 5, 6, 9, 10, or 11). The `analogWrite` function provides a simple interface to the hardware PWM, but doesn't provide any control over frequency. (Note that despite the function name, the output is a digital signal, often referred to as a square wave). For example, if it is required to actuate Thruster01 in clockwise direction at 50% PWM and other Thruster02 in anticlockwise direction at 70% PWM, then just by giving the command "a 50 -70" through serial monitor, it can be achieved. The letter 'a' is used to initialize the thrusters and the negative sign defines anti clockwise orientation and without an signed variable defines clockwise orientation For giving "a 0 0", both the thrusters will stop. It has been implemented through ROS too.

V. HARDWARE SETUP

Building a model in solidworks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of solidworks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

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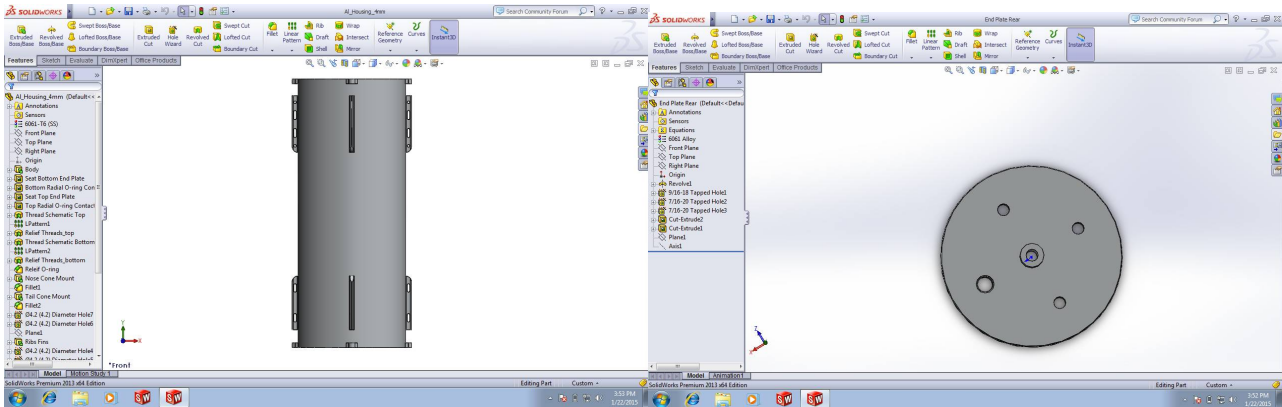


Fig.3 Side view of the Hull in Solidworks Fig. 4 Nose Plate of the Hull in Solidworks

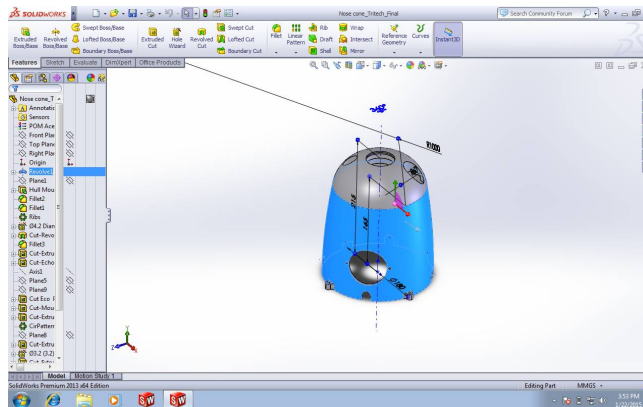


Fig.5 Side view of the Nose Cone in Solidworks

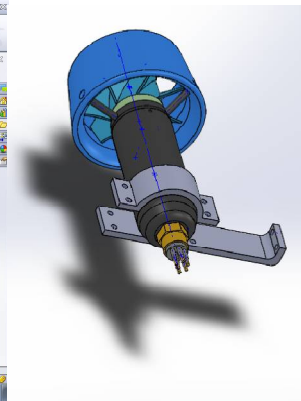


Fig. 6 Thruster setup in Solidworks

There are total of twelve part in this ASV, which consists two hulls, two nose plates, two tail plates, two nose cone, two tail cone, one thruster placing part and another is the RF part. These has been designed by keeping many constraints in mind. After all of these got manufactured, then the assembling took place. After doing that, the biggest challenge was making it float on the water surface which has been acquired easily.

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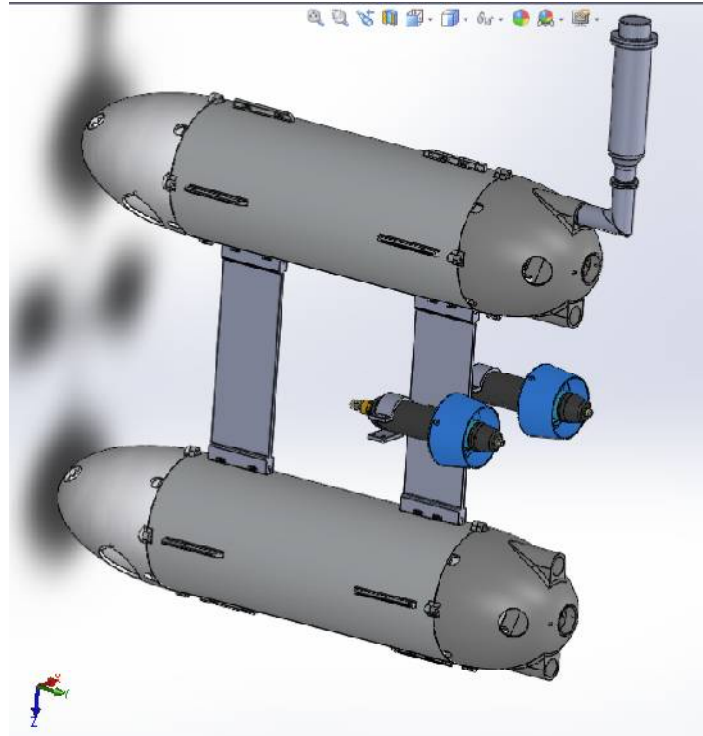


Fig.7 Isometric view of the ASV in Solidworks

VI. RESULT & DISCUSSION

Power management for ASV is desired for many reasons, particularly:

- Reduce overall energy consumption
- Prolong battery life for portable and embedded systems
- Reduce cooling requirements
- Reduce noise
- Reduce operating costs for energy and cooling

Lower power consumption also means lower heat dissipation, which increases system stability, and less energy use, which saves money and reduces the impact on the environment. For the power management, several DC-DC converters, N-MOSFET, Gate Triggering Circuit are required. DC-DC are needed for converting the source voltage to the multiple isolated voltages for different applications. N-MOSFET is require to switch among the DC DC converters and Gate Triggering Circuit is need to turn on the N-MOSFET completely, so that it won't create unwanted heat. In eagle board, the schematic diagram of the power management system has been drawn. It is needed to convert 24 VDC to 5V, 12V, 18V and 24V DC maintaining high efficiency and at least 2 Amp current rating. Hence opting the VICOR DC DC Converter for this purpose was beneficial. Normal N-channel MOSFET used for fast switching. Gate Driver circuit is used for making the N-MOS completely turned on in order to get rid of the heat loss. Hence the MIC-501 has been used. The Arduino kit gets the power (5V input) through a DC DC converter and using that. The switching has benn controlled. Capacitors are used in the input and output side of the DC DC Converter.

EAGLE contains a schematic editor, for designing circuit diagrams. Parts can be placed on many sheets and connected together through ports. The PCB layout editor allows back annotation to the schematic and auto-routing to automatically connect traces based on the connections defined in the schematic. The connection from Arduino is

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coming to the gate driver circuit having 4 pins. The output of it goes to the N-MOS and makes it completely on and the output from that goes to the DC DC converter which converts the input 24V to the desired output voltage (i.e. 5V/12V/18V/24V).

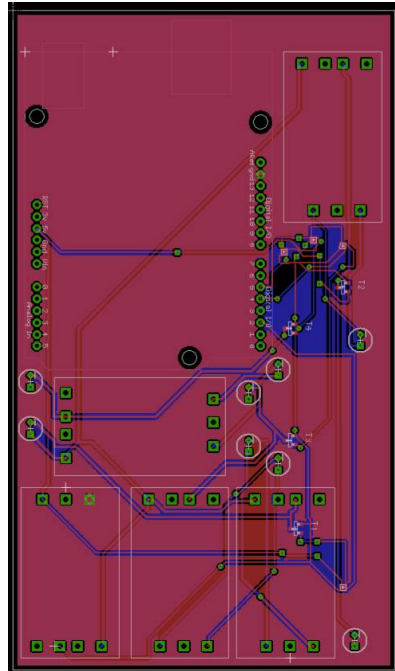


Fig.8 PCB Design

In eagle board the packaging has been done and formed a board which will be having the Arduino to get embedded itself on it and other elements will also get embedded on that. The PCB layout editor allows back annotation to the schematic and auto-routing to automatically connect traces based on the connections defined in the schematic. The PCB design includes all the 5 DC DC converters, 4 Gate triggering circuits, 4 N-channel MOSFETs along with the Arduino and required capacitors. While computing the schematic diagram, the VICOR DC-DC converter libraries wasnot there in the EAGLE Board library section. So the library has been created and put it under consideration.

VII. CONCLUSION

While autonomous surface vehicles are in their infancy, it was believed that tremendous opportunity exists for modular and customized ASVs if some hurdles can be overcome. In addition to saving money over existing systems, ASVs also offer benefits that are currently unmatched by existing systems that include endurance missions, collection of data in hazardous environments, and swarm behavior that can use multiple units to gather data more quickly. The capacity of autonomous surface vehicles to be used for environmental monitoring and ocean task performance will serve to improve the understanding of the oceans, which will in turn benefit the interaction between society and the environment.

The testing phase and the integration part has been done for this project. The PCB layout which has been designed, that got printed. The solid works model has been done keeping many constraints in mind and the electronic elements have been shortlisted after well study. After the successful installation of all the modules, it worked accurately and it was a great success. The solidworks models have been crafted and they are assembled in proper order. The communication part has been done separately. During the testing phase, a few problems has been encountered and it was solved on spot as they were very minor problems.

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VIII. APPENDIX - ARDUINO CODE

```
#include <TimerOne.h>
#include <ros.h>
#include <auv_test/ThVoltMsg.h>
const char MotorPin1 = 9;
const char BrakePin1 = 6;
const char DirPin1 = 11;
const char MotorPin2 = 10;
const char BrakePin2 = 8;
const char DirPin2 = 12;
shortintreadflag=0;
shortintfirstread=1;
int dutyNum1,dutyNum2;
floatdutyCycle;
longlastping=0; //-----ROS ros::NodeHandlenh;
int th1,th2;
int prevth1,prevth2;
charcmdid;
voidmessageCb( constauv_test::ThVoltMsg&tmp){ digitalWrite(13, HIGH-digitalRead(13)); // blink the led //
Serial.println("Hello");
th1 = tmp.thvolt1;
th2 = tmp.thvolt2;
cmdid = tmp.cmd;
readflag=1;
lastping=0;
}
ros::Subscriber<auv_test::ThVoltMsg>sub("Th- volt", messageCb );
void callback(){ if(lastping>500)
{
digitalWrite(BrakePin1, HIGH); digitalWrite(BrakePin2, HIGH); noInterrupts(); Timer1.pwm(9,dutyNum1);
Timer1.pwm(10,dutyNum2 ); interrupts();
}
elselastping++; }
void setup() {
Serial.begin(9600);
Serial.println("Hello");
pinMode(BrakePin1, OUTPUT); pinMode(DirPin1, OUTPUT); digitalWrite(BrakePin1, LOW); digitalWrite(DirPin1,
LOW);
pinMode(BrakePin2, OUTPUT); pinMode(DirPin2, OUTPUT); digitalWrite(BrakePin2, LOW); digitalWrite(DirPin2,
LOW); //Tperiod = 10000; // in micro seconds //-----
pinMode(13, OUTPUT); nh.initNode(); nh.subscribe(sub); prevth1=th1; prevth2=th2;
dutyCycle=50;
Timer1.initialize(10000); Timer1.attachInterrupt(callback);
dutyNum1 = (unsigned int)(dutyCycle*1023/100); dutyNum2 = (unsigned int)(dutyCycle*1023/100);
Serial.print("Duty Cycle "); Serial.println(dutyCycle);
Serial.print("Duty Number "); Serial.println(dutyNum1); Serial.println(dutyNum2); Timer1.pwm(MotorPin1,
dutyNum1); Timer1.pwm(MotorPin2, dutyNum2);/(dutyCycle / 100) * 1023);/ (dutyCycle / 100) * 1023
}
void loop()
{
nh.spinOnce();
if(readflag){
readflag=0;
if(firstread){
delay(400);
if(th1<0){
digitalWrite(DirPin1,HIGH);
noInterrupts();
Timer1.pwm(11,dutyNum1 );
interrupts();
}
if(th2<0){
digitalWrite(DirPin2,HIGH);
```

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```
noInterrupts(); Timer1.pwm(12,dutyNum2 );
interrupts(); } firstread=0; }
else{
if((th1>0)&&(prevth1<0)){ // for checking sign change delay(500);
digitalWrite(DirPin1, LOW);
noInterrupts();
Timer1.pwm(11,dutyNum1 );
interrupts(); }
else if((th2>0)&&(prevth2<0)){
delay(500);
digitalWrite(DirPin2, LOW);
noInterrupts();
Timer1.pwm(12,dutyNum2 );
interrupts(); }
if((th1<0)&&(prevth1>0)){
delay(500);
digitalWrite(DirPin1, HIGH);
noInterrupts();
Timer1.pwm(11,dutyNum1 );
interrupts();
}
else if((th2<0)&&(prevth2>0)){
delay(500);
digitalWrite(DirPin2, HIGH);
noInterrupts();
Timer1.pwm(12,dutyNum2 );
interrupts();
}
}
/** Some part of code has been hidden due to classified issues**//
delay(80);
} //delay(500); }
```

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