Notions Co.
for Advanced Marine Technology and ROVs

Sweeping the Blue Earth!

PASCAL

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NotionsCo.

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Abstract

This technical report is written to describe the ROV known as "PASCAL". PASCAL is constructed by Notions Co. to complete mission tasks related to installation, operation, and maintenance of regional cabled ocean observing systems. The major innovation this year is building a work class dry hull ROV with vector thrust. This new combination has vouched high speed and performance, easy maneuverability and uniqueness in shape. Regular reference to hydrodynamics and classical mechanics, and simulating the suggested designs were the fundamental approach used in every step during building the ROV. PASCAL integrates a clear acrylic electronics can that contains all the circuits, eight 1100GPH thrusters, and 4 high resolution cameras to provide a wide field of view during mission execution. The ROV is tethered using two 25m data wires each of 6 lines and 2 power cables. The tether transfers data from the ROV to the driving station and vice versa. The driving station contains an electric board, display screens and a Graphical User Interface implemented using LabView and C# which displays the sensors' data and aids in measuring the length of the designated location. Other payload tools are the vertical levelers used to level the secondary node and the hook centered at the bottom of the ROV to carry heavy objects as the SIA. Safety precautions have been on the top of the list where the staff managed to build a well-isolated ROV with a thermal protection system. The total budget of PASCAL is $1931.26 including reused materials.

Notions Co. staff

Staff from left to right:
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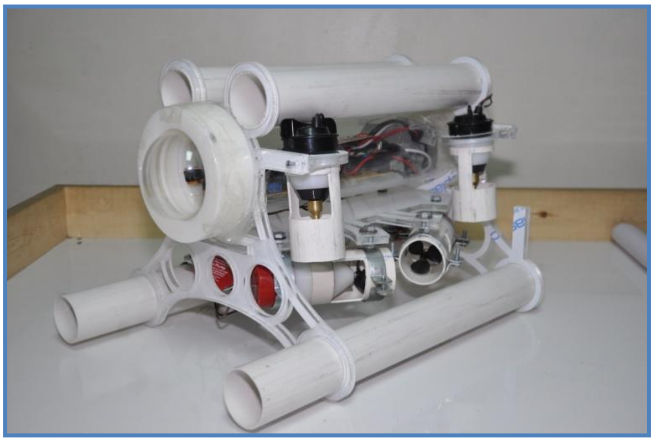
Special Features:

- Dry hull system with vector thrust
- PASCAL has its own driving station
- A graphical user interface is designed
- Pan and tilt system is used for camera
- Very thin tether with little drag



Real photo for PASCAL

Design rationale

PASCAL is characterized by a compact frame (56cm L x 40cm W x 35cm H), light weight and very stable body as all the weight is distributed equally and symmetrically.

1. Frame

Notions Co. managed to develop the frame of its previous product (SINDBAD) yet without affecting the pressure and the water flow on the vehicle. The mechanical department started looking up for a compromise between good shape, low pressure and steady streamline water flow. After doing some trials and research, the dry hull system has proven to be exactly what the company is looking for. This is due to its cylindrical shape, which has a very low water resistance, a steady flow and an equal distribution of forces which gives very high stability in water. Notions Co. has succeeded in developing a better ROV design - with all the required specifications - as compared to the previous company's product (SINDBAD).

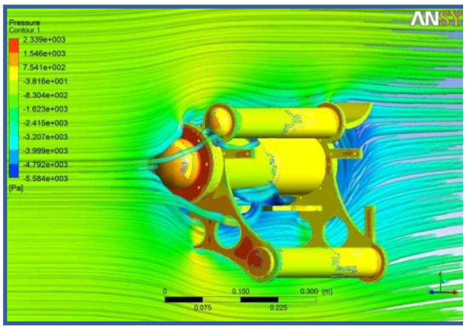


Fig.1: Pressure contour

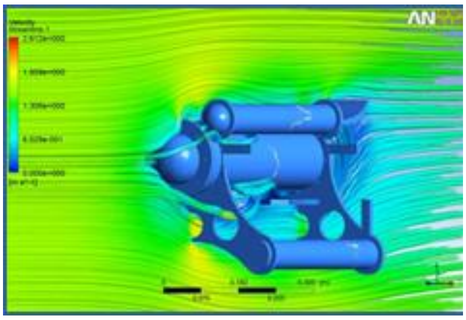


Fig.2: Velocity streamline

Fig.1 represents the pressure force on the ROV body at a speed of 1m/s and it shows that a very small area (represented by the dome and the front sheet) is subjected to maximum pressure which is low as compared to the high thrust force of the motors used. Moreover, the rest of the body does not experience any unbalancing forces.

Fig.2 shows that water resistance on the ROV's main frame is very low. It simulates the streamline flow at a speed of 1 m/s where the flow is very steady with some water turbulence behind the ROV which does not affect the robot's maneuverability or balance.

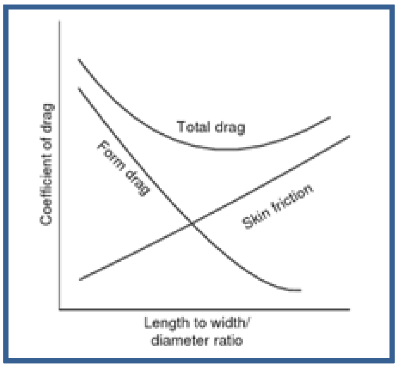


Fig.3: Relation between diameter and drag

The ROV simulations presented in Fig.1 and Fig.2 were performed using 7-equations (Reynolds stress) instead of K- ε, which improved the results as the pressure decreased to three quarters of the values calculated using the K-ε.

PASCAL was modeled and tested step by step on SolidWorks and ANSYS programs until Notions Co. came up with the most suitable. PASCAL's fundamental body structure consists of: 1 electronics can (EC), 2 skids, 1 sheet for fixing the horizontal motors and 2 domes.

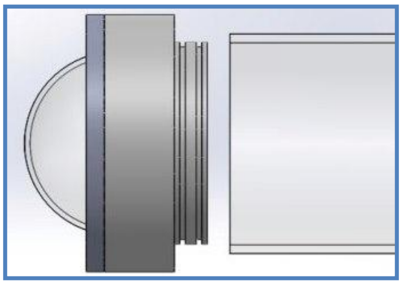


Fig.4: Dome, end cap and cylinder

The EC is composed of an optically clear acrylic cylinder of an inner diameter 11cm and thickness 0.5cm which endures very high pressure. The ratio between the length and the diameter of the cylinder is 4:1, which is the ideal ratio to significantly reduce the skin and form drags on the cylinder yet have a wide enough EC to contain all the circuits [1]. This is clearly shown in Fig.3.

Calculating the drag on the body:

$$Drag = \frac{1}{2}\sigma A_v V^2 C_{dv} \quad (1)$$

The EC is tightly closed with 2 polyethylene end caps of diameter 10.9cm and thickness 1.5cm. Each cap has 2 O-rings incorporated in it to sustain complete sealing. A plastic dome of radius 5cm is fixed on each cap to enclose the cameras from both sides, which allows fore and aft movement of the ROV. Fig.4 depicts the structure of the dome, end cap and the cylinder.

The EC is held using 2 acrylic skids of thickness 10mm. The skids also hold the rest of the components as thrusters, manipulators, spotlights and others. An additional horizontal sheet, also made of 10mm acrylic, holds the motors responsible for the ROV's movement in the horizontal plane.

2. <u>Motors setting</u>

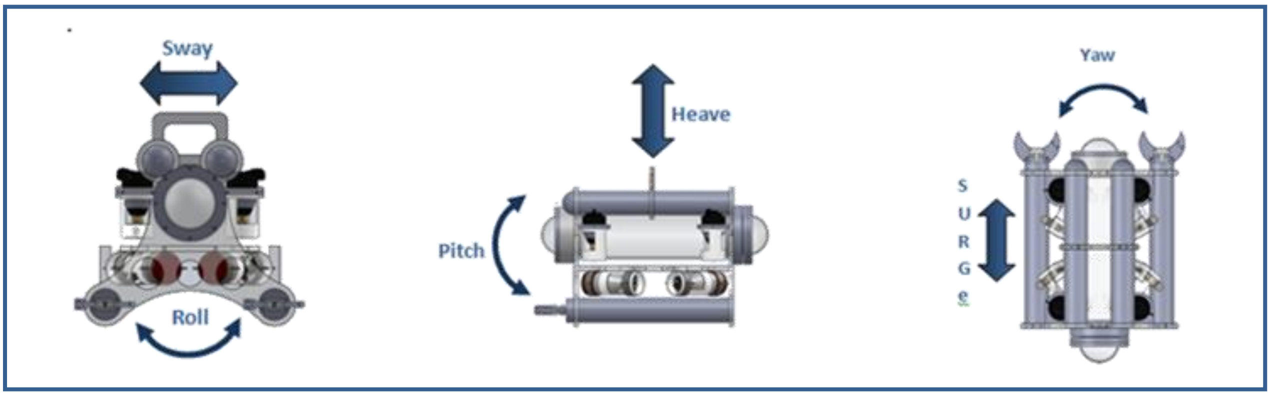


Fig.5: Degrees of freedom of ROV

Fig.5 shows the six degrees of freedom of the ROV, PASCAL which contains 8 motors:

2.1 4 Motors for heave, pitch and roll movements

Each pair of motors is fixed at the bow and stern of the ROV forming a rectangular shape of 30cm x 21cm (LxW).

2.2 4 Motors for surge, yaw and sway movements

One of the special features of PASCAL is the horizontal vector movement, as shown in Fig.6. The motors are fixed by metal collars from one side and the other side slides to change the slope of the motor starting from zero up to 30° with the vertical line so that the maximum speed of the motor can be varied. The minimum distance between the motors when set at angle zero is 10cm, which is wide enough to provide a very stable motion.

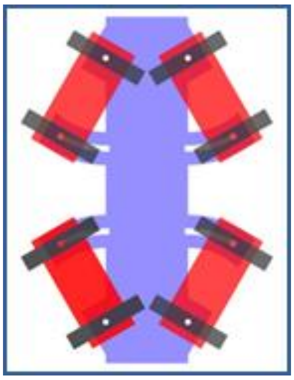


Fig.6: Motors' sheet

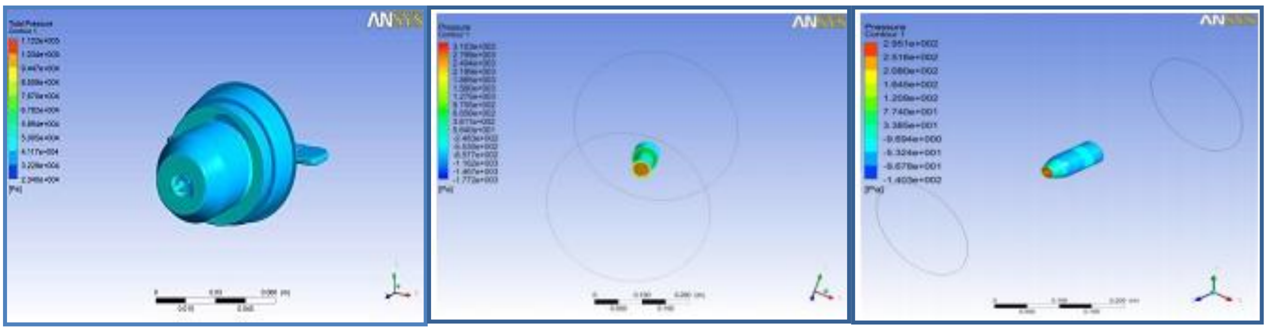


Fig.7: ANSYS simulation for motor with and without housing

Centre of rotation:

The ROV design managed to set the motors such that the centre of rotation coincides with the centre of gravity.

3. Motor housing

3.1 Thrusters' housing

As shown in Fig.7, housing each motor with a polyethylene casing proved its efficiency by providing a steadier streamline water flow and lower water pressure on the motor's body thus reducing water turbulence. The rest of the ANSYS simulation graphs for the motor's body are found in Appendix C.

3.2 manipulators' motor housing

The manipulators' motors are completely isolated using a polyethylene casing covered by an end cap with an O-ring incorporated in it. A detailed diagram is presented in Fig.8.

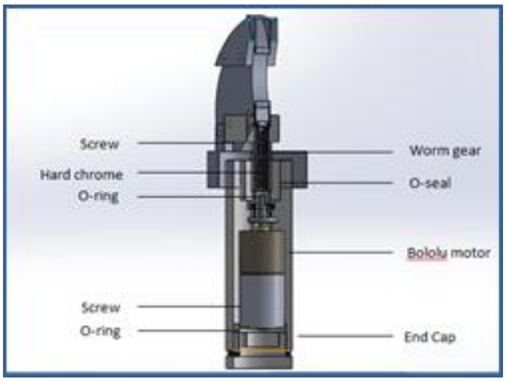


Fig.8: cross section of manipulator

4. Lighting

To make PASCAL more close to the real ROV applications, Notions Co. used a pair of spotlights operated using on/off switches at each of the bow and stern of the ROV. This maintains clear vision during the performance of the required missions as the light intensity is maximum at the air-sea interface and decreases gradually as the ROV dives deeper into the water eventually reaching zero at almost 20m under clear sky conditions as presented in Fig.9 [2]. This case is not applicable for the ROVs' normal diving range.

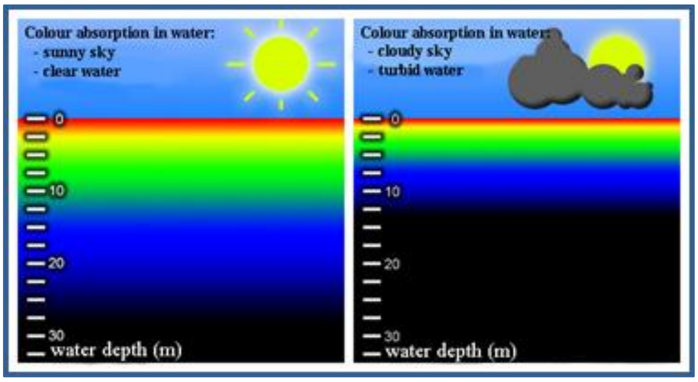


Fig.9: Colour absorption chart

5. Floating and buoyancy

High centre of buoyancy and low centre of gravity was a primary concern in building up PASCAL to give the camera platform maximum stability about the longitudinal and lateral axes and balance the body rapidly if any vibrations occurred. Using two cylindrical air chambers would be more efficient than using a sheet of cork or fiberglass because placing sheets above the ROV's body would slightly block the water flow thus inducing extra drag.

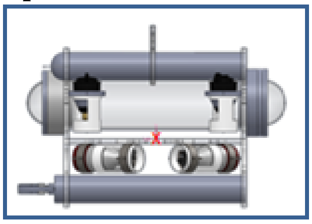


Fig.10: Centre of gravity calculated on SolidWorks

Centre of gravity:

PASCAL's centre of gravity is almost at the centre of the ROV as the tools and motors were placed symmetrically, as shown in Fig.10.

The centre of buoyancy:

The centre of buoyancy of the ROV is directly above the centre of gravity by 10cm.

Referring to Fig.11, the amount of air needed for zero buoyancy is calculated:

Total weight of the ROV=mg= 6.2 x 9.81=60.822N (2)

Up thrust= $\rho g \Delta h A = 1000 \times 9.81 \times 0.35 \times (9.33\times10^{-3})$ (3)

$= 32N$

F_{net}=weight-up thrust = 60.822-32 = 28.822N

$\because \rho_{water} = 1000\ kg/m^3$

$\therefore$ Weight of 1 m^3 of water= 1000 x 9.81=9810 N

Volume of air needed $= (28.822 \times 1\ m^3)/9810$

$= 2.94 \times 10^{-3}\ m^3$

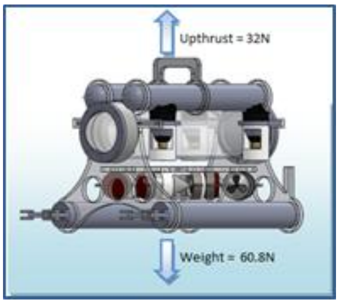


Fig.11: Forces on PASCAL in water

Accordingly, two air chambers are installed to the ROV; each of radius 1.91cm and length of 40cm. So, by adding both the air inside the electronics can and the air inside the air chambers, slight positive buoyancy is maintained so if the communication with the ROV is lost, it directly returns to the surface.

6. Handles

A firm acrylic handle is fixed to the air chambers at the top of the ROV to ensure safe handling of our ROV and for easier transportation.

7. Tether splitter

The tether splitter is placed away from the body by ½m where it carries the weight of the umbilical cable (the part of the tether from the splitter to the water's surface) as shown in Fig.12, so that the buoyancy of the ROV is not affected. Furthermore, it allows easier transportation as the tether can be separately transferred.

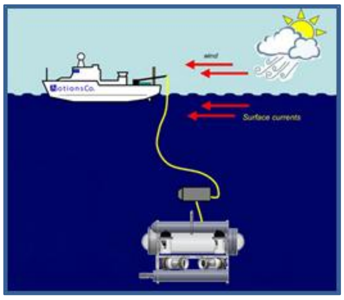


Fig.12: Tether Splitter

Calculating drag on umbilical cable [1]:

$$Drag = \frac{1}{2}\sigma A_v V^2 C_{dv} \qquad (4)$$

8. Clamps

PASCAL contains 2 parallel clamps specially designed for the required missions. The clamps are sized to firmly hold the circular structures like the CTA.

Payload Tools

1. Transmissometer

1.1 Mechanical structure

A PVC structure was designed as shown in Fig.13 in which the sensor is placed. This structure is installed to the vent field from 4 points using cone structures made of polyethylene.

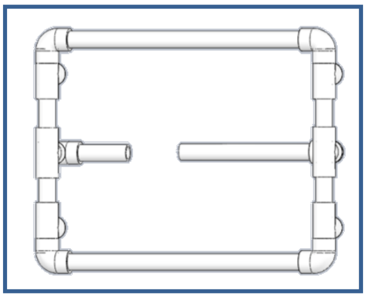


Fig.13: PVC structure

1.2 Electrical structure

Fig.14 illustrates the components of the sensor and the idea of its operation. It is composed of a photo resistor and a laser beam fixed on a very thin electric board. The board consists of a microcontroller which takes an ADC reading from the photo resistor then sends it to the laptop in the driving station. The board is placed inside the PVC structure at one side of the rotating disk and the laser beam is placed at the other side.

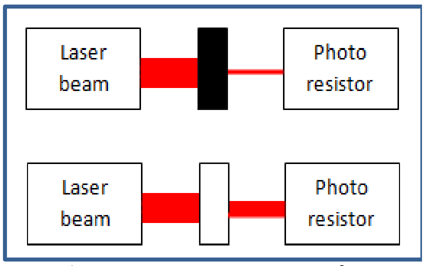


Fig.14: How sensor works

1.3 Software

The electric board sends the data using serial communication. The laptop reads the signal and draws a graph of the results using Labview as shown in Fig.15.

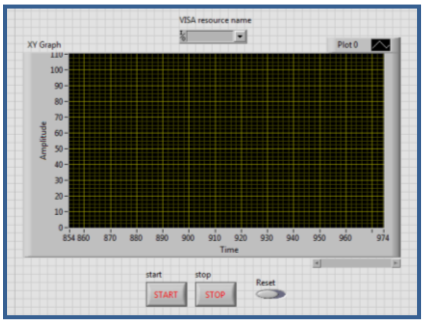


Fig.15: Labview interface


Fig.16: Visual studio interface

2. Measuring distance of the designated location

A software is coded using C# to measure the distance of the designated location using the front camera. The camera captures an image of the location and sends it to the laptop where the user has to select 2 points with a known distance between them and the 2 points of the required distance. By carrying out several calculations, the distance is accurately measured and displayed on the GUI as shown in Fig.16.

3. Hook

A hook shown in Fig.17 is centered at the bottom of the ROV to carry heavy objects as the SIA from the centre of the body so the ROV's balance and stability do not get affected.

Fig.17: Hook

Fig.18: VL

4. Vertical levelers (VL)

Two manipulators are fixed vertically at the stern of the ROV where a PVC T-connector is cut into half and attached to each motor as shown in Fig.18 to adjust the legs to level the secondary node as the connector rotates.

Electrical System and Software

1. Electronics:

PASCAL's electrical system is composed of 4 modules any of which can be easily replaced when any failure occurs.

1.1 Conversions

All the conversions take place on-board of the ROV. Four buck converters are installed to step down the 48V to 12V. The buck circuit is illustrated in Fig.19.

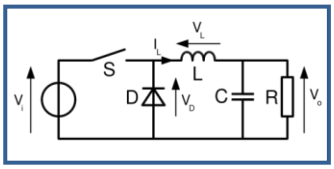


Fig.19: Buck circuit

The system contains 4 converters:

1.1.1 Driving motors converters:

The average current each driving motor needs is about 5A, so each 4 motors are supplied by 1 20A converter. PASCAL contains 8 driving motors, so 2 converters are used.

1.1.2 Manipulators' motors, control system and cameras converters:

Fig.20: 5A converter

The control system and the cameras consume about 350 mA, so a 5A buck converter shown in Fig.20 was built to step down the voltage to 12V for the control system and cameras.

A separate 5A converter is designed and built for the manipulator's motors, where each motor consumes about 1.5A, so the total voltage if all the manipulators are operated together is 6A as PASCAL contains 4 manipulators' motors. However, not all the manipulators are used at the same time. Notions Co. built a separate converter for the manipulators so that if any jamming occurs, the whole system will not get affected.

Motor	Propeller		Thrust forward/kg	Thrust backward/kg	RPM	Current/A	
						Forward	Backward
Bilge Pump	5cm	Left	0.75	0.50	7600	4.0	3.9
		Right	0.75	0.50		4.0	3.9
Johnson Pump	5cm	Left	1.10	0.76	7638	4.0	3.8
		Right	1.00	0.75		4.0	3.6

Fig.21: Sample of the results

1.2 Motors

Notions Co. uses 3 different types of motors to build PASCAL: Rule pumps, Johnson pumps and Bololu motors. Testing was the criteria to pick out the motors that would be used for this year, so several tests were carried out on different combinations of motors and propellers in order to obtain the best compromise. (A sample of the results is presented in Fig.21)

<u>1.2.1 1100GPH Rule pump</u>

To minimize the expenses, Rule pumps were installed from last year's project in Notions Co.'s third generation. Rule pumps are operated using a 12V supply. Four Rule pumps are used for the surge, yaw and sway movements where they are fixed and can be deviated with different angles.

As shown in the above results, Rule pumps have reasonable current drainage (4A) yet produce a strong enough thrust (0.75Kg) to maintain fast and smooth movement for the ROV. To assure the results of these tests, the motor is simulated using MATLAB® software as shown in Fig.22.

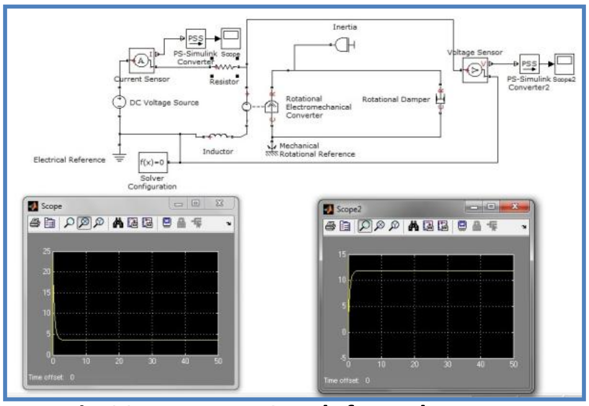


Fig.22: MATLAB Graph for Rule pump

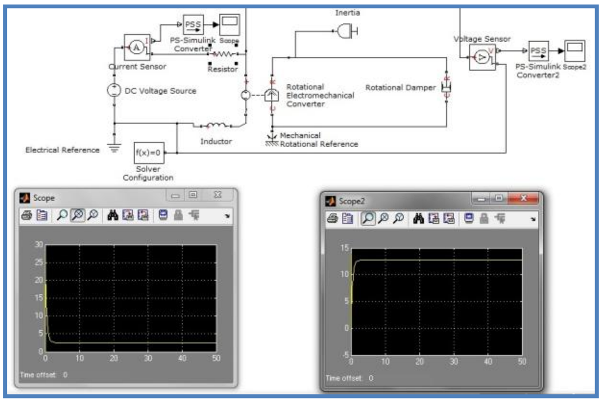


Fig.23: MATLAB Graph for Johnson pump

<u>1.2.2 1100GPH Johnson pump</u>

Always seeking development, Notions Co. introduced Johnson pumps to the ROV. From the above tests, it is shown that Johnson pumps have higher thrust (1.1kg) than Rule pumps with the same current drainage (4A) and the same operating voltage (12V). Having higher thrust than Rule pumps, 4 Johnson pumps are used for the heave, roll and pitch movements so that the ROV easily carries heavy weights as the SIA.

Johnson pump is also simulated on MATLAB as shown in Fig.23.

For both thrusters 5cm left propellers are used as this combination provides high thrust with the most reasonable current drainage.

<u>1.2.3 Bololu motors</u>

Four Bololu 12v motors of 180 RPM are used for the manipulators. These motors have high torque of 8.8 kg/cm which holds the clamps very tight so that the robot can carry and transfer heavy objects safely and without big loads on the motors. In addition, these motors are so compact and light which makes them occupy less space in the vehicle.

Fig.24: pan and tilt system

Fig.25: CCTV camera

1.3 Cameras

One of the primary aspects Notions Co. focused on while designing the ROV is to provide a clear and broad vision for the working area and the ROV's payload tools. Therefore, 3 high resolution cameras are installed to cover a very wide range of view field (almost 300^{o} on the vertical plane).

Fig.26: waterproofed camera

1.3.1 Pan and tilt camera

This camera is enclosed inside the front dome. The pan and tilt system is depicted in Fig.24. The system is composed of a set of spur gears, powered by 2 servo motors, to rotate the camera and is capable of providing a 180° field of view in the vertical and horizontal planes.

1.3.2 CCTV camera

This camera shown in Fig.25 is placed at the back dome of the ROV to allow bidirectional movement and to view the water balance while adjusting the legs to level the secondary node.

1.3.3 Waterproofed camera

This camera shown in Fig.26 is mounted on the hook and the Vertical Levelers to provide an unobstructed field of view during mission execution.

A wide angle lens of view angle 170° in air and 85° in water is attached to each camera to cover a wider range.

1.4 Driving Station (DS)

The driving station shown in Fig.27 is built in order to make a full ROV system as much close as in real life applications.

Fig.27: Driving station

The DSC consists of:

1.4.1 Display screens

Two 7.8’’ screens are used to display the image of the waterproofed camera and the CCTV camera placed at the stern of the ROV.

1.4.2 Driving Station Circuit (DSC)

The DSC shown in Fig.28 receives the sensors’ readings from the on-board circuit to display them on 2 LCD screens (4 x 16) and process this data to take any action if needed. In addition, this data is sent to a laptop using serial ports to be displayed. The driving arms are connected to the DSC using USB connector. An analogue joystick is connected to the DSC to control the pan and tilt system of the front camera. The DSC interfaces the driving arms and sends this data to the on-board circuit using serial communication to operate the motors.

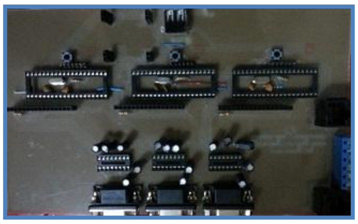


Fig.28: DSC

1.4.3 Driving Arms

Notions Co. interfaced 2 driving arms shown in Fig.29:

- *Gamepad*

  An electric board is specially designed to operate the Gamepad and send the data to the driving station using serial communication.

- *Joystick*

  An electric board is specially designed to operate the Joystick and send the data to the driving station using serial communication.

Fig.29: Driving arms

1.4.4 Laptop

The laptop receives the sensors’ and the transmissometer’s readings from the DSC and displays them using LabVIEW software. In addition, it receives a signal from the front camera to perform image processing and calculate the distance of the designated location to install the secondary node.

1.5 Tether

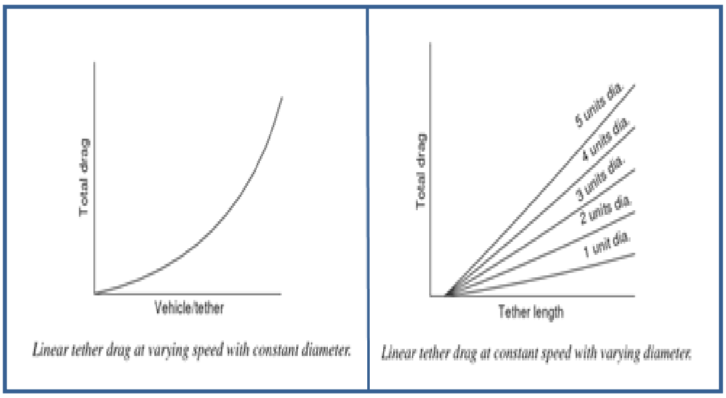


Fig.31: Tether drag

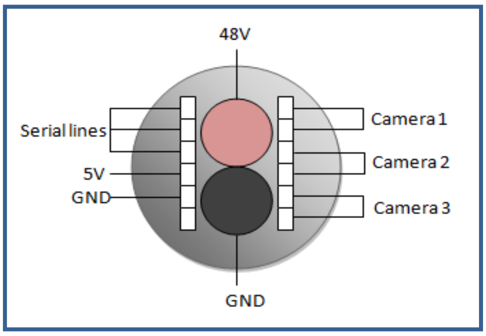


Fig.30: Tether lines

PASCAL is tethered with a 25m two data wires (each has 6 lines) and 2 power lines as shown in Fig.30. The cables are firmly attached together using PVC insulation tape.The tether weights 324g and has a diameter of 0.4cm. The relations between the tether drag and the speed, and the diameter are illustrated in Fig.31. The coefficient of drag of cables ranges from 1.2 for unfaired cables; 0.5-0.6 for hair-faired cable; and 0.1-0.2 for faired cables which depends on the diameter of the cable. Since the cylindrical form has the highest coefficient of drag, the use of cable fairings to aid in drag reduction can have a significant impact [1]. Therefore, Notions Co. managed to reduce the coefficient of drag of the tether to 0.2 (faired cable) by the diameter reduction.

1.6 On-Board Circuits (OBC)

<u>1.6.1 Control Module (CM)</u>

Fig.32: CM

The CM shown in Fig.32 receives the data of the motors from the DSC and communicates this data to the relay modules. In addition, it sends the sensors' readings to the DSC to be processed and displayed.

Five sensors are interfaced in the ROV:

- *Temperature sensor:*

Model: LM35

Usage: four temperature sensors shown in Fig.33 are put inside the electric can to monitor the temperature of the can. The sensor has an output voltage that is proportional to the Celsius temperature by scale factor of $0.01V/^{0}$ C. It covers a range from −55°C to +150°C [3].

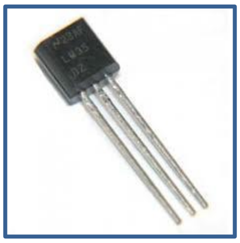


Fig.33: Temp. sensor

- *Water sensor:*

Model: Seeedstudio Electronic Brick Water Sensor (RB-See-199)

Usage: 2 water sensors are placed in the electronics can as a safety precaution to detect any water leakage.

This sensor shown in Fig.34 works by having a series of exposed traces connected to ground and interlaced between the grounded traces are the sensors traces. A resistor inside the sensor will pull the sensor traces value high until a drop of water shorts the sensor trace to the grounded trace. Consequently, as the amount of water increases, the output voltage increases. The sensor outputs an analogue reading [4].

Fig.34: Water sensor

- *Current sensor:*

Model: Allegro® ACS758 family of current sensor

Usage: eight current sensors are placed in the electric can: 1 for each motor to monitor the current drainage of the motor so that over current drainage or failure of any of the motors can be detected.

The current sensor shown in Fig.35 consists of a precision, low-offset linear Hall circuit with a copper conduction path located near the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage with scale factor 40 mV/A. The output of the device has a positive slope (>VCC / 2). It can detect current up to 25A in both directions [5].

Fig.35: current sensor

- *Digital compass:*

Model: Honeywell HMC6352 Compass Module (#29323)

Usage: A digital compass shown in Fig.36 is used to determine the heading of the ROV relative to the north.

The HMC6352 Integrated Compass Sensor circuit is composed of two magneto-resistive (MR) sensors with orthogonal orientation for sensing the horizontal components of the earth's magnetic field (0 to 630 milli-gauss), plus two amplifiers, a set/reset drive circuit, and a microprocessor (µP). . It outputs the data in 2 bytes using I2C communication protocol [6].

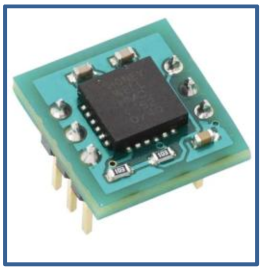


Fig.36: Compass

- *Tilt sensor:*

Model: MX2125

Usage: Tilt sensor shown in Fig.37 is used to measure the angle of tilt in x-axis and y-axis.

The MX2125 has a chamber of gas with a heating element in the center and four temperature sensors around its edge. When the accelerometer is level, the hot gas pocket rises to the top-center of the chamber. By tilting the accelerometer, the hot gas will collect closer to some of temperature sensors. By comparing the sensor temperatures, The MX2125 converts the temperature measurements into signals for microcontrollers to measure [7].

Fig.37: Tilt sensor

<u>1.6.2 Relay Modules (RM)</u>

Two RMs are used as ON/OFF switches to operate the motors. Each module consists of 15 relay as shown in Fig.38 which provides bi-directional movement to the motors. A special feature of the RMs is that for each relay, an LED is used to indicate if the relay is working.

Fig.38: RM

2. <u>Software:</u>

Graphical User Interface

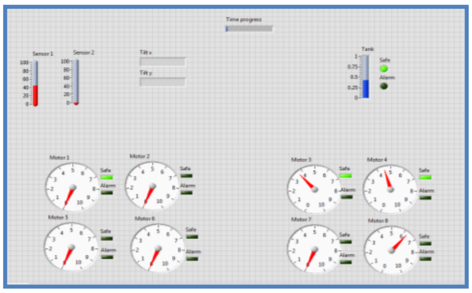


Fig.39: GUI

Notions Co. designed a GUI as shown in Fig.39 to display the sensors readings using LabVIEW software. The GUI consists of several widgets: current for each motor, water detection, roll-pitch, temperature, safety LEDs, match progress and others. Important information is always clearly visible for the pilot. The DS periodically provides data exchange between ROV and widgets to be displayed for the pilot. This GUI is proved to be quite handy and convenient to use during the training sessions. It's quite visually, informative and handy.

Safety Precautions

1. ROV safety:

1.1 Mechanical

- The end caps of the electronics can are isolated by a layer of thick wax as the motors' wires pass through them.
- O-rings are incorporated into the end caps to maintain complete isolation at very high pressure. Isolation was at a pressure up to 2 bars.
- All edges are smoothed.
- Kort nozzles are attached to the motors with safety stickers.
- A firm handle is used to safely handle the ROV.
- A safety rope is tied to the ROV to pull the ROV in water when needed.

1.2 Electrical

- Ten fuses are installed in the ROV:
  - 40A fuse connected to the power line of the tether placed in the DS
  - 5A fuse on each motor
  - 1A fuse on control module
- A current sensor is connected to each motor to give an alarm if high current drainage occurred due to jamming.
- Temperature sensor monitors the temperature of the circuits and if the temperature exceeded 60^{o}C, the system gives an alarm on the LCD screens and GUI then shuts down automatically.
- Water detection alarm is operated if any leakage in the electronics can is detected.
- Safety switch is placed in the DS to shut down the system if needed.

2. Staff safety:

Notions Co. staff managed to follow some safety precautions in order to avoid injury and stay safe throughout the whole working duration:

- Wearing eye goggles during cutting and building the mechanical body.
- Using fixed tools like the drill station instead of the drill to avoid any injuries.
- Wearing gloves and lab coats while printing and welding the electric boards.
- Wearing headphones during using the saw station to block its high sound from the user as shown in Fig.40.
- The workshop contains a first aid box for any injuries.
- All the electric batteries are stored separately from each other and from the electric boards to prevent any short circuits.

Fig.40: Hossam Amr using the saw station

Budget

Categories	Detailed components		Price per each/$	Number of Items	Total price/$
Mechanical	Acrylic cylinder		28.6	1	28.6
	1. Acrylic sheets		28.6	5	143
	2. Arms mechanisms		49	4	196
	3. Tether splitter		11	1	11
	4. PVC 1 Inch		4.5/m	2 m	9
	5. Propellers		12.2	8	97.6
	6. Ball bearing		0.6	8	4.8
	7. Motor housing		5.71	8	45.68
	8. Kort nozzle.		1	8	8
	9. Dome.		21.5	2	43
	10. Pan & tilt camera system		10	1	10
	11. Motor axils		5	8	40
Electrical	1. Johnson Pump motors		51.5	4	206
	2. *Bilge Pump motors		42.9	4	171.6
	3. Arms Motors 180 RPM		14.82	4	59.28
	4. DC to DC convertors 5A		12.2	2	24.4
	5. DC to DC convertors 20A		71.5	2	143
	6. *CCTV Camera		28.5	2	57
	7. *Underwater Camera		100	1	100
	8. Wires & data wires.		1/m	100 m	100
	9. Electrical components “µc, resistors, capacitors, ICs & etc….”		142.8	--	142.8
	10. Sensors:	• Current sensor	10	8	80
		• Water sensor	4.3	1	4.3
		• Temp sensor	1	4	4
		• *Tilt sensor	35.75	1	35.75
		• *Digital compass	35.75	1	35.75
		• Transmissometer	7.2	1	7.2
Other	11. Team shirts		6.5	8	52
	12. Wasted materials		71.5	--	71.5
Total					1931.26

Notes:

“*” reused materials.

AAST-IGCSE department contributed by paying us $300. The rest of the budget is self-paid.

Troubleshooting

1. Jammed motor:

One day during the usual working process the control board stopped functioning without any obvious reasons! We started tracing the problem starting from the driving station to the on-board circuits. After some hours of investigating the problem, we discovered that the microcontrollers on the board had been burnt depending on the theory that when power is supplied, burnt components no longer perform their functions and act like a simple load which heats up: more current - more heat. With the gradual increase of input current and temperature monitoring of the board components, it was obvious that the microcontrollers had been burnt. However, it took us some time to discover that this was due to jamming in an old motor we were using from last year which caused very high current drainage and consequently the board was burnt. The motor was directly replaced with another one and a separate converter was built for the control system. In addition, a current sensor was installed for each motor to monitor its current. So, if jamming occurs the high current drainage can be directly detected and the system is shut down before it fails.

2. Leakage in the electronics can:

After building the ROV, Notions Co. started testing the isolation in a swimming pool at depth 7m. A very little water leakage in the electronics can was detected. So, using a compressor we started checking every part of the ROV by blowing air through it and noticing any out-coming air bubbles in the water. The reason of the problem was directly identified as the end caps of the electronics can leaked some water through the holes made in them to pass the motors' wires into the can. After several failed tests with covering the holes with epoxy and silicon, we decided to fill the end caps with melted wax so that it takes the shape of the cap becoming a part of it when it solidifies. Finally, we made our successful test without any water leakage.

Fig.41: Ahmed Hamdy working on the ANSYS simulations

Challenges

1. Technical

The major challenge we faced during this working experience is in our robot's design. At first, we designed our dry hull with larger dimensions; however, after we completely finished our ROV's design on SolidWorks and simulated the body using ANSYS software, it was discovered that the size of the dome required was not available. The only available size was a dome of radius 5cm. Now, we had 2 options whether to use the small dome with the bigger body frame which would have been unsightly, or redesign a smaller body. It was a really challenging job to design the same ROV with all the needed tools in much less space! So, we designed an extra sheet to hold the motors required for the horizontal motion.

Fig.42: Nouran is skype-meeting with the rest of the team

By this, the whole size of the ROV is reduced in return to a slight increase in the height which still looks pleasing. Changing the size of our ROV caused other consequent problems in the on-board circuits as we had to limit the dimensions of all the electric boards to the new size of the electronics can in order to place all of the required components inside. We started reducing the size of our PCBs as much as we can which was extremely time-consuming until we finally placed all our circuits successfully inside the new electronics can.

2. Non-technical

2.1 Skype meetings:

As high school students, our studies are very demanding as we are being prepared for the coming years in college. As a result, we always had a problem to hold a regular meeting in which all the company's staff would attend. However, this never affected our progress in the working process as we found another solution. We held regular Skype meetings to make sure every team member kept track of the tasks, updates and To-do lists.

2.2 New company staff:

This year our company employed new staff members. This formed a big challenge in organizing our work and jobs as it was their first experience in MATE ROV. To overcome this problem, the old staff members held training sessions at the beginning of the working process to introduce the competition to the new staff and to teach them all the technical experience the old staff gained from the previous years of participation to make sure the same quality of work is maintained and to ease the work. At first, when dividing the tasks we made sure an old member would work with a new member in order to help him/her understand the process. Senior staff began to train newer staff in certain tasks and operations, so that the techniques and information could be absorbed and passed on throughout the entire company. This ensured important corporate knowledge would be preserved and would not have to be re-established within the company, taking precious time away from future projects. Soon, all the company became closely experienced in the job and each individual started producing outstanding work. Furthermore, it is now a lot easier to divide the tasks upon all the members as they are well experienced.

Fig.43: Sondos El-sayed welding the electric boards

Future improvements

The future improvements Notions Co. plans to implement are:

- Designing an electrical system that communicates using Ethernet protocol in order to allow driving over IP (DoIP) using silver light software, so the ROV can be driven remotely over internet.
- Using a fiber optic tether which is lighter, thinner and allows very fast data transfer. In addition, it is not affected by noise and data can travel through it very large distances without attenuation. This will significantly reduce the diameter of the tether and therefore reduces the drag force on the tether. Consequently, the maneuverability of the ROV will be improved.
- As an improvement for our marketing plan, Notions Co. will develop a game for its ROV to represent the ocean exploration theme and the importance of the role of ocean observing systems. Our ROV will be the vehicle which the user explores the ocean with. The user will have some mission calls and has to get them done.

Lessons and skills learned

1. Technical

Fig.44: Dina and Mariam working on SolidWorks

Our company's project for this year "PASCAL" has been a very rewarding experience to every member in the crew. Starting with the newcomers to underwater robotics, this coursework has added up a lot to their technical knowledge and practice. For instance, the electrical department is now well-trained to design and finish up high-quality electric boards using Altium software in a very short period of time. Simultaneously, the mechanical department has developed very wide knowledge in hydrodynamics which has always affected every small aspect of the robot's design. In addition, they have managed to learn several programs in order to simulate every step of building our ROV such as SolidWorks and ANSYS. Speaking of ANSYS, this year we managed to improve our simulations by using seven equations instead of just two which reduced the forces and the pressure on our vehicle by ¼ of the old values.

Fig.45: Ahmed Ehab writing down the budget

It was a new experience to the whole staff building a GUI using LabView software to display the ROV's status for the pilot and to measure the length of the designated location using C#. For the sake of reducing mission time, an idea was presented to utilize a non-mechanical method of measuring the distance to find the designated location for installing the secondary node. By flying over the designated location, the front camera captures an image of the designated location. The image is then processed and stored in a bitmap. The user selects 2 points on the screen with a known real distance between them and then selects other 2 points which bound the required length. The pixels location coordinates are subtracted from each other to get the number of pixels between the 2 points. By getting a relation between the number of pixels and the real length, the distance is calculated accurately with an error of few millimeters.

Fig.46: Shrouk and Nouran sketching the electrical diagram of the system

2. Interpersonal

The GOLDEN rule: "The key is not spending time, but in investing it" Stephen R. Covey. Time management as known as "The GOLDEN rule" is the most important interpersonal lesson we have learned throughout the whole experience. From the beginning of the coursework, we have scheduled a time plan for our work so that the working time does not interfere with school work. At first, it was very easy to finish the tasks besides studying. However, as the competition approached the load of work increased so all of us had to spend more time finishing their tasks. In order to make the process less stressful for the crew, the company setup a very cool policy for the work: each member has 2 hours daily to work in his/her task for 5 days, Fridays are off and Saturdays are full-time. This policy proved to be very successful and handy as all the team members without exceptions managed to finish up all the tasks in time and excel in school.

Reflections

"Working at Notion Co. is really something that I am proud of as being a new member in this company has affected my character and way of thinking deeply. There I found all the senior staff very helpful and eager to share their experiences with the newcomers. I had the chance to apply the scientific principles I have been studying in Math and Physics on the ROV's body which really made me discover another meaning to these rules other than a word problem question in the exam! In the end, I think what makes our company special is our strong belief in "One for all and All for one". "

Shrouk Ashraf, Electrical engineer

Fig.47: Sondos El-sayed developing the electric board

"Although it is my second year in underwater robotics, the competition this year has added up a lot of meanings and qualities to my personality. To me, sharing is on the top of the list! I have seen the powerful meaning of sharing our ideas and experiences together in every step throughout the whole project. I remember that time when we had to resize our ROV because the size of the dome we wanted was not available, in other words we had to REDESIGN it! Being closer to the competition time, we were extremely stressed and worried to hear such bad news, however, we held an urgent meeting in which 1 person started sharing his idea and the rest has started upgrading it one-by-one until we came up with our recent design. It was really amazing how every one of us inspired the other by simply adding his thoughts and ideas!"

Nouran Soliman, CEO

Fig.48: Nouran Soliman working on the GUI

Fig.49: Nouran Soliman is helping one of the other team members in understanding hydrodynamics

"This experience is the most rewarding experience I have ever had. Apart from having so much fun during our coursework, I have learned a very important lesson that reflected on my whole life and decisions: Implement your ideas. Working in the mechanical department, it was my first time to put my ideas for the ROV's design into action and observe the consequences. Whether my idea was successful or not, this aided to build up my experience which made me do better the following time. Now, I have a wider vision that I can expect the consequences of a certain idea and most probably get them right"

Dina Wael, CAD designer

NotionsCo.

Team work and organization

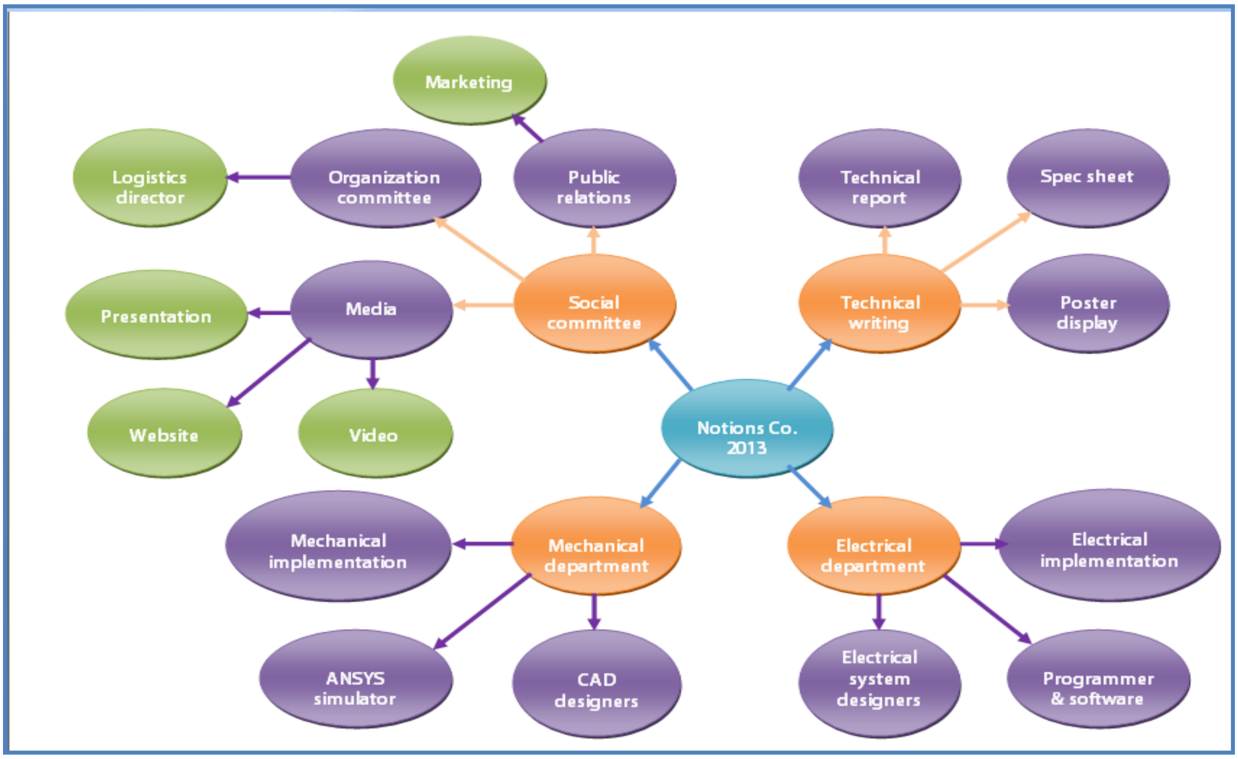


Fig.50: Job's diagram

To beat the clock, Notions Co. staff has setup a full working system and schedule from the first day of work. At first, a "Job's" chart with all the tasks was block-diagramed as shown in Fig.50 to have a clear image of the whole process. In addition, a Gantt diagram was scheduled to be our timeline through the coursework as shown in Fig.51. In order not to have a stitch in time, a weekly To-do list was hung in our workshop so that if any delay occurred it would not affect the whole time plan. At the beginning of our technical work, tasks were divided so that each senior works with a new staff member in order to transfer experience to them so the company thrives in the future. On a weekly basis, a meeting was held so each department explains its work to other members and the logistics director discusses our progress rate. This helped to ensure that the ROV was completed with as much time to practice before the competition as possible.

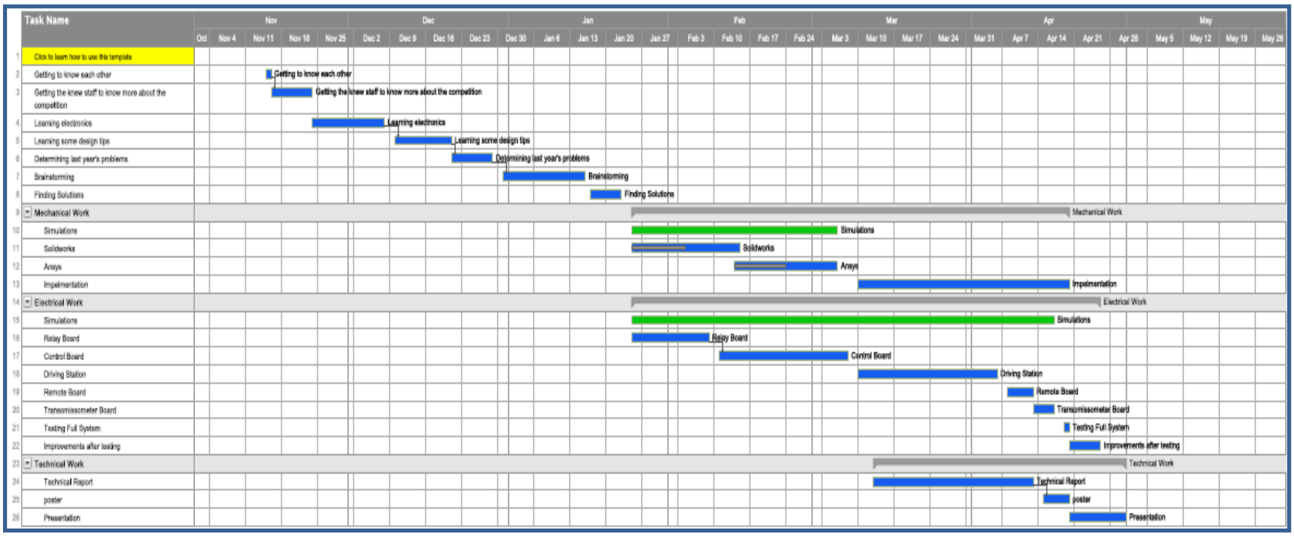


Fig.51: Gantt diagram

Outreach

Our vision is an Image of the future we want to create by combining our knowledge and experiences to idealistically benefit our community. We are looking to the near future to improve this field in our community and to enhance the methods of exploration of the blue earth. It is the dream that we survive to accomplish. As a first step, we started helping out new students interested in underwater robotics. Although, our help was limited to giving them advice and explaining some technical subjects to them, Notions Co. aims to expand its activity to spread this field. In addition, our senior staff conducted a presentation in Faculty of Engineering, Alexandria University, to recall their experience in underwater robotics and present their work.

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5) Current sensor
URL: www.pololu.com/file/download/ACS715-Datasheet.pdf?file_id=0j197 Retrieved on: 27/03/2013
6) Digital compass
URL: https://www.sparkfun.com/datasheets/Components/HMC6352.pdf Retrieved on: 08/02/2013
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URL: http://www.parallax.com/Portals/0/Downloads/docs/prod/sens/28017-Memsic2Axis-v2.0.pdf Retrieved on: 15/02/2013

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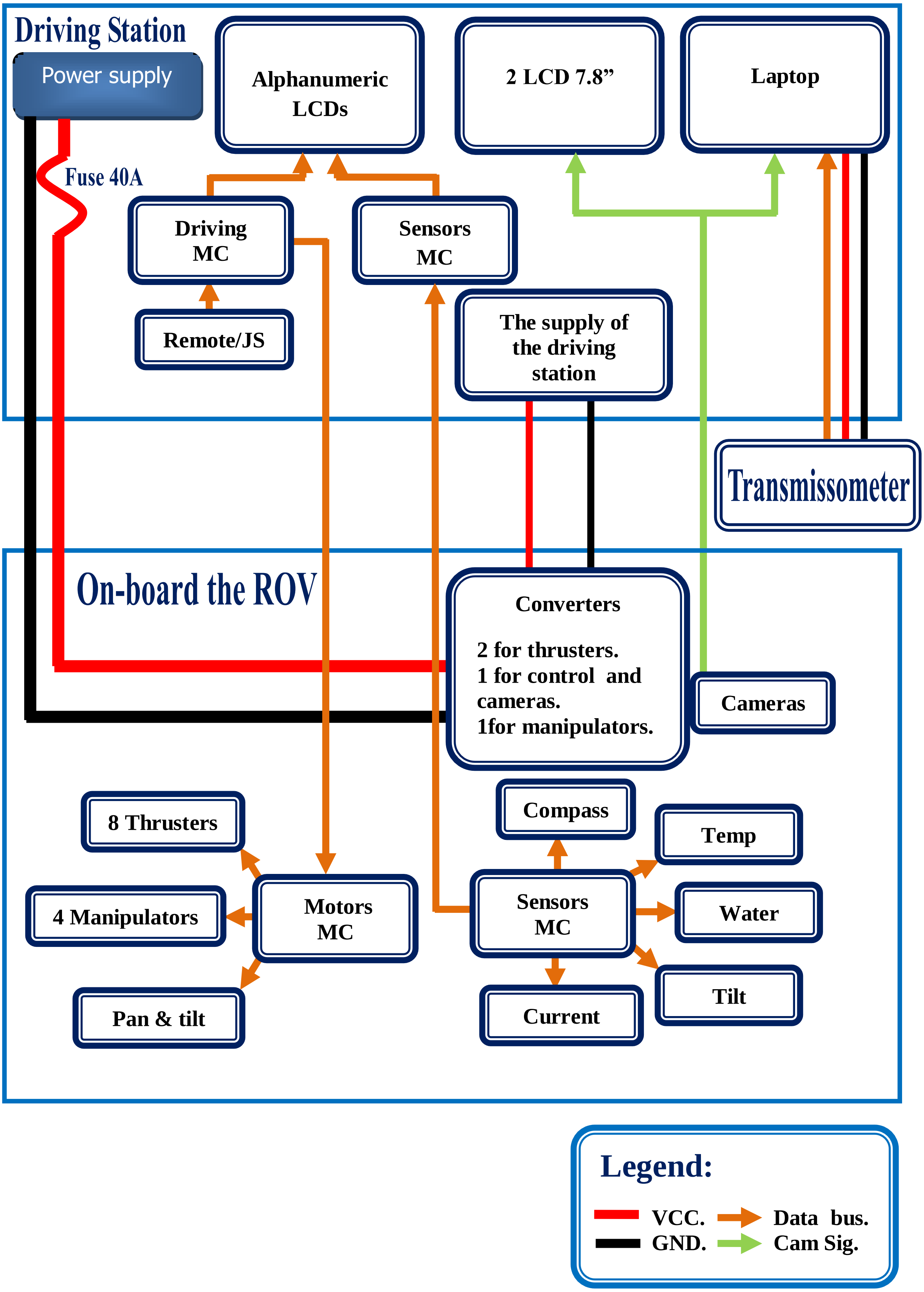
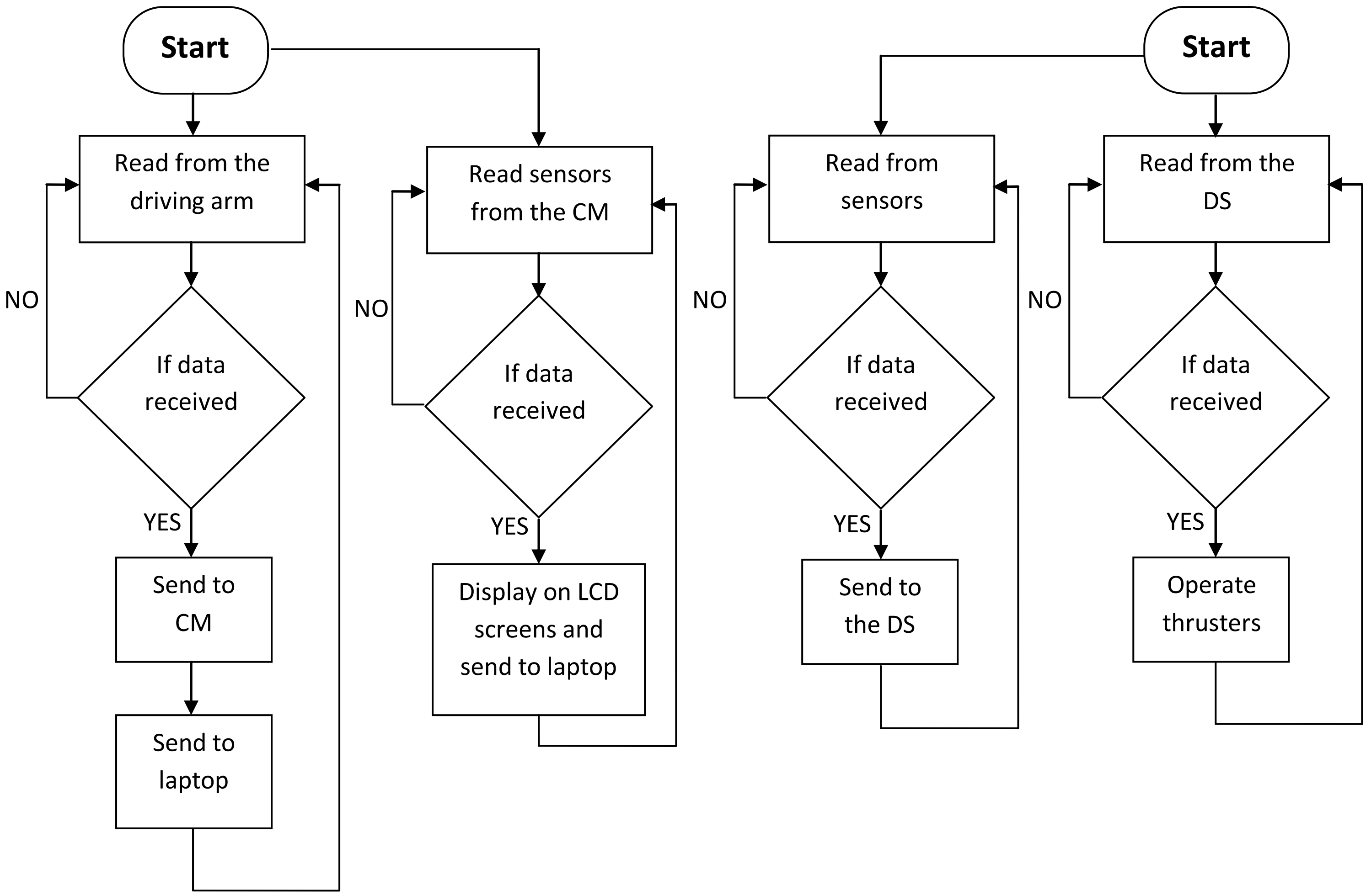
Special thanks to the MATE Centre for giving us the chance to participate in this competition.
Finally, we wish to thank the Arab Academy for Science, Technology and Maritime Transport – IGCSE department for sponsoring us.

Appendix

Appendix A: Electrical diagram of the system

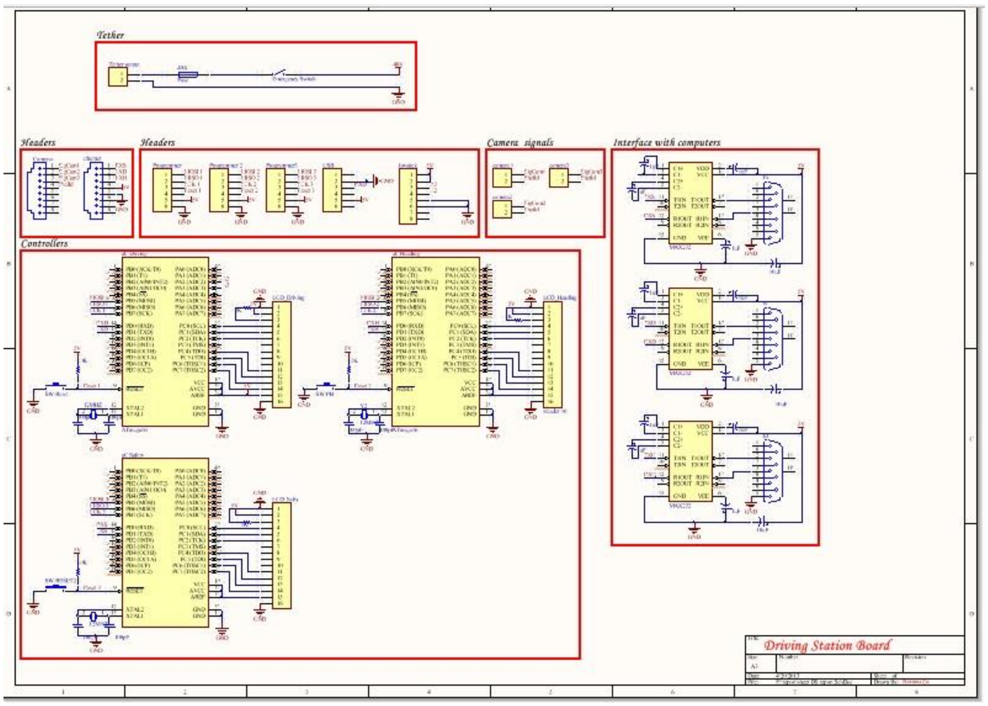


Appendix B: Programming Flow chart

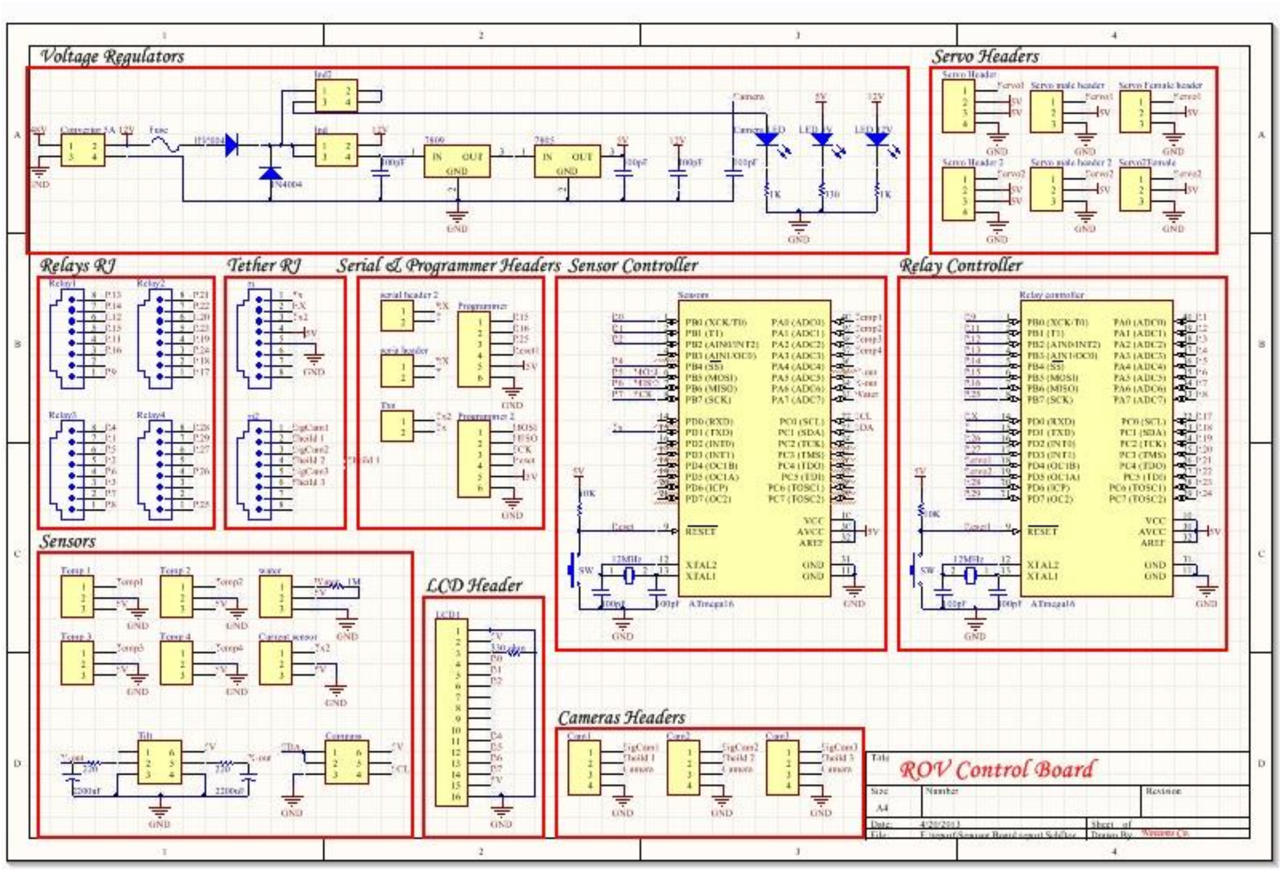


Appendix C: Electric schematics

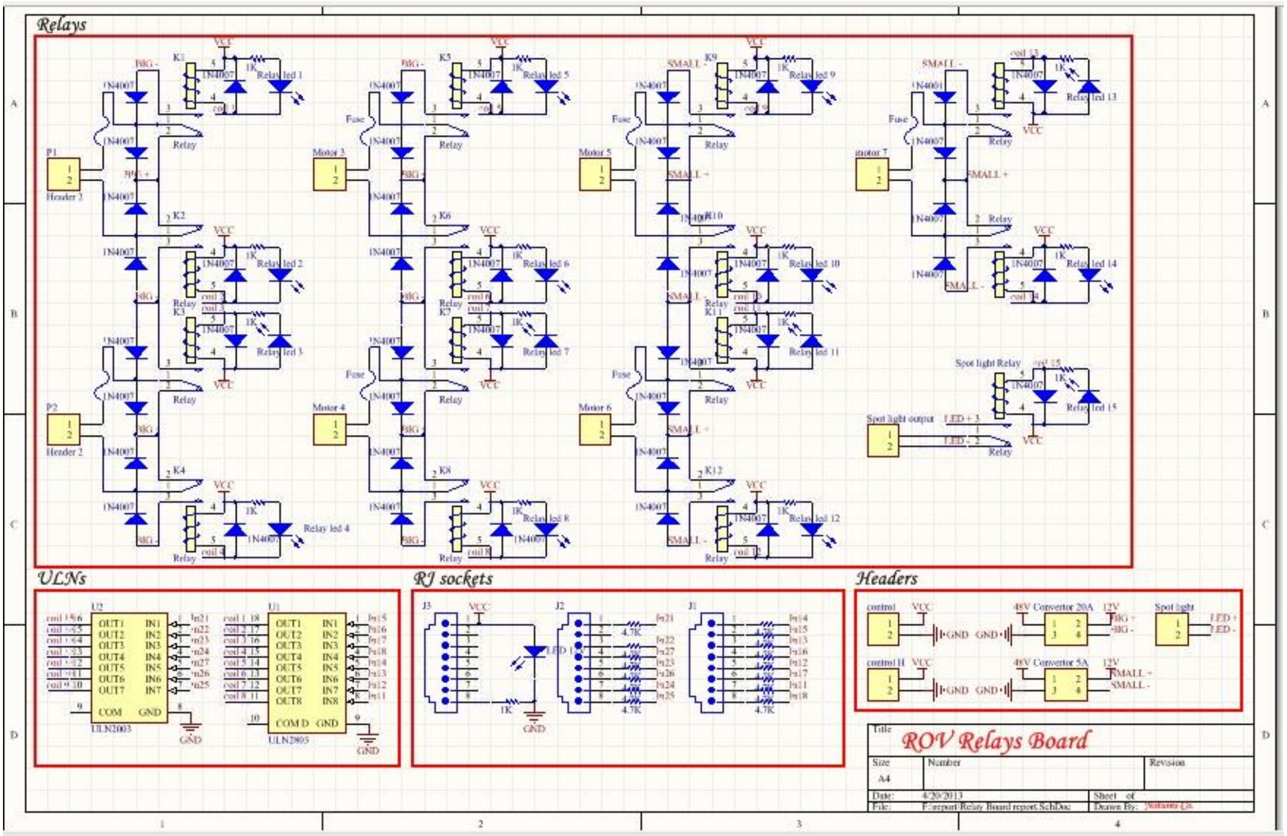
Driving station schematic



Control board schematic

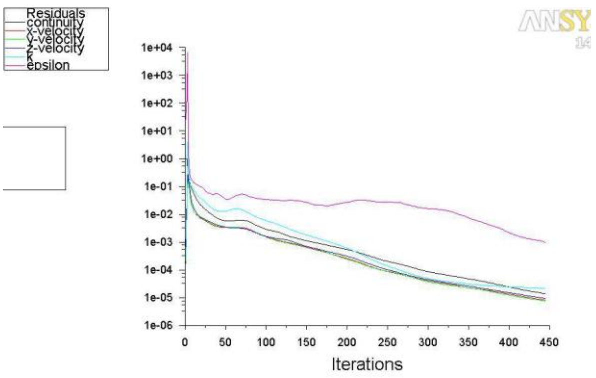


Relay board schematic

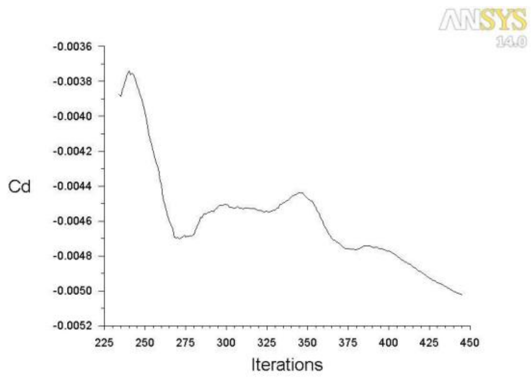


Appendix D: ANSYS simulation graphs for thrusters at depth 4 m

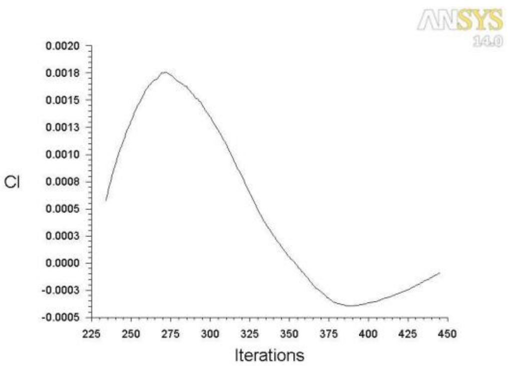
Residual error for the motor body



Coefficient of drag of the motor body

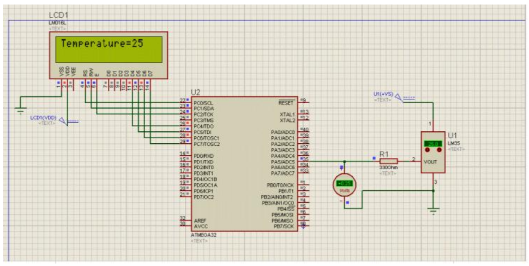


Coefficient of lift of the motor body

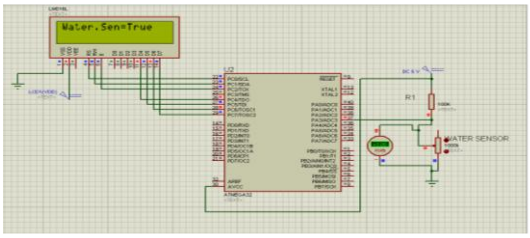


Appendix E: Proteus simulations

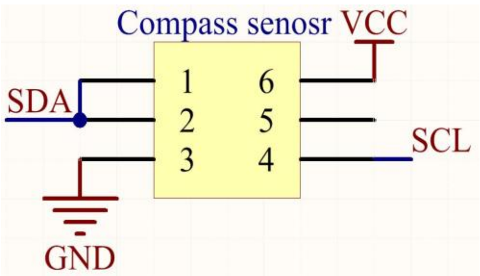
Temperature sensor



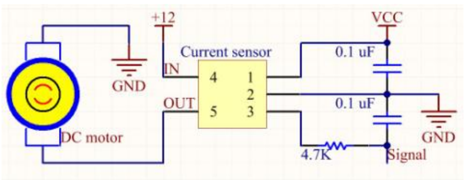
Water sensor



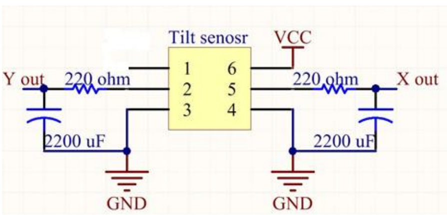
Digital compass



Current sensor



Tilt sensor



Appendix F: Safety checklist

Mechanical Safety checklist

Before Work:

- ✓ Do not wear loose clothing or jewelry.
- ✓ You must wear protective equipment, such as goggles, safety glasses, masks, gloves, hair nets, ear protectors ,etc
- ✓ Be sure such equipment is adjusted for you. Safety equipment such as restraints, pull backs, and two-hand devices are designed for your protection.
- ✓ Pile materials, skids, bins, boxes, or other equipment so as not to block exits.

During work:

- ✓ Never distract the attention of another person.
- ✓ Keep your work area clean.
- ✓ Do not exceed a speed that is safe for existing conditions.
- ✓ Do not adjust, clean, or oil moving machinery.
- ✓ Do not throw objects.

After Work:

- ✓ Shut down your machine before cleaning, repairing, or leaving it.
- ✓ Clean up spilled liquid, oil, or grease immediately.
- ✓ Return all tools to their places.

Electrical Safety checklist

Before Work:

- ✓ Make sure that there is no wet floors
- ✓ Never use equipment with frayed cords, damaged insulation or broken plugs.
- ✓ Always use appropriate insulated rubber gloves and goggles while working on any branch circuit or any other electrical circuit
- ✓ Tie Your hair
- ✓ Never use aluminum or steel chairs
- ✓ Do not wear jewelry

During Work:

- ✓ Always use insulated tools while working
- ✓ Always use a circuit breaker or fuse with the appropriate current rating.
- ✓ Never try repairing energized equipment. Always check that it is de-energized first by using a tester.
- ✓ Observe circuit shortcuts before energizing your board.
- ✓ Include circuit breakers or fuse before testing your board.
- ✓ Keep the solder iron in its stand when not in use

After Work:

- ✓ Remove all Plugs.
- ✓ Place isolating sheets between your boards before storing
- ✓ Wait for solder iron to cool before storing