Little Deep
by DEEP Robotics

British Columbia Institute of Technology
Burnaby, British Columbia
Canada

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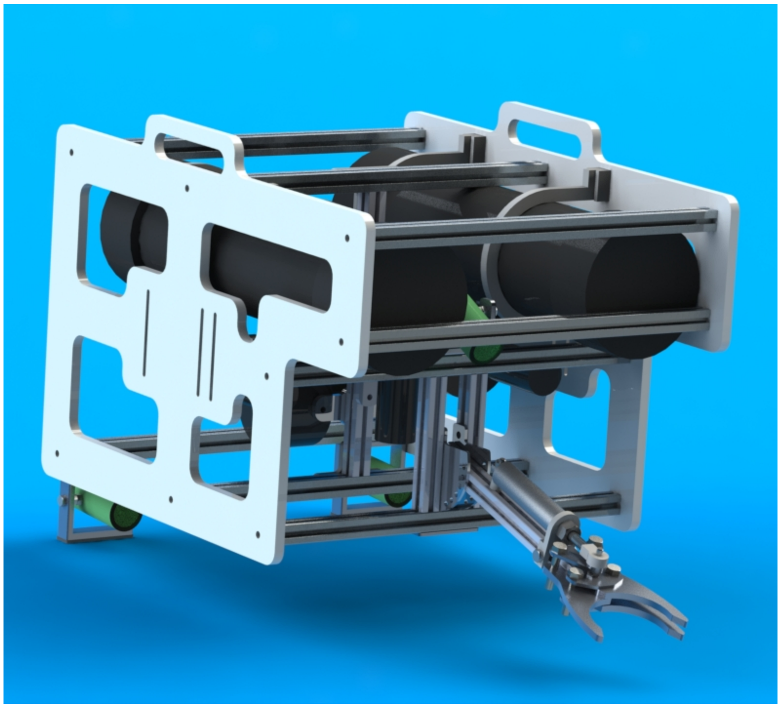


Company Members (Graduating 2014)

Jason Hunter – CEO – Mechanical Engineering Technology
Brett Oystensen – Documentation Lead – Mechanical Engineering Technology
Kieran McIntosh – Modeling Lead – Mechanical Engineering Technology
Michael Brosch – Manufacturing Lead – Mechanical Engineering Technology
Bill Morris – Mechatronics Lead – Mechatronics & Robotics

Sponsor/Supervisor:
Taco Niet

Abstract

DEEP Robotics is a marine engineering company that designs, manufactures, and operates a variety of underwater robotic platforms. The skills of our five team members include mechanical engineering and robotics expertise applicable to marine activities.

As part of our research and development activities over the last five months, we have designed, built and tested a new Remotely Operated Vehicle (ROV) platform named Little Deep, which was designed and built specifically for the exploration of shipwrecks in coastal waters. Little Deep is an ROV that is capable of a variety of tasks including shipwreck identification, ecological sampling, and marine conservation. It was fabricated using the extensive shop facilities at BCIT and wherever possible, cutting edge technologies, such as CNC water jet cutting, were used.

The design team determined the best components and configurations to use for Little Deep by implementing several concept evaluation methods including a system morphology and decision matrices. Upon completion of the decision matrices, detailed designs were developed and the following items were fabricated and incorporated into the working ROV. The main tooling platform of the ROV was designed and constructed using water jet cut polyethylene side panels with aluminum extruded cross members, which combine to create a durable and stable foundation for the remaining systems. A four thruster configuration was chosen for programming simplicity while maintaining a comprehensive range of motion, including, crab walking ability. A pneumatic gripper was built using specific contours to allow manipulation of a broad range of objects to suit many situations, including PVC bottles and sensor strings. A core sampler with directional fins was built to allow core sampling of bacterial communities. Cameras were positioned in particular locations along the bottom of the ROV in order to create a viable camera parallax that can be used to measure the length and height of objects. The control system of the ROV was built using two Arduino devices, surface module and ROV module, which communicate along the tether to quickly convert command inputs into system outputs.

The abilities of Little Deep are directly related to real world underwater applications. Whether there are requirements for shipwreck exploration and recovery, ecological monitoring and sampling, or debris removal and toxic waste disposal, this ROV is equipped to complete the job. All these applications combine to create an extremely versatile state-of-the-vehicle, with vast and continuously increasing potential.

Acknowledgements

The ROV design team would like to thank the following faculty and classmates:

- Taco Niet, P.Eng, M.A.Sc (B.Eng Program Head)
- MATE – Marine Advanced Technology Education
- BCIT - School of Energy
- Jason Brett, Cert IETE, B.Ed, M.Ed (Technology Teacher Education)
- Dave Lewis, B.A.Sc, (Manufacturing Program Head)
- Eugene Duruisseau, TQ (Machining)
- Greg King, P.Eng, M.B.A (Mechanical Engineering)
- Chris Baitz, AScT (Robotics & Mechatronics)
- Brent Dunn, P.Eng, M.Eng (Robotics & Mechatronics Program Head)
- Dan Green (Classmate)
- Graham Stewart (Classmate)

Taco Niet not only guided the team to design and manufacture a functioning underwater ROV, but also shared his passion for underwater marine exploration. Without his experience and guidance, the design team wouldn't have been able to complete the prototype on deadline for the MATE Pacific Northwest Regional Competition on May 10, 2014 in Federal Way, Washington. Weekly meetings with Taco Niet, Bill Morris (robotics & mechatronics) and the mechanical design team kept the team heading in the right direction throughout the duration of the project.

Jason Brett shared his knowledge of electrical systems and mechatronics, as well as provided many small electrical components, which were needed during the manufacturing of the prototype.

Dave Lewis, Eugene Duruisseau, and Greg King all helped with manufacturing the prototype and provided us with the ability to use BCIT's shop facilities.

Brent Dunn set up a tour at International Submarine Engineering (ISE) near the beginning of this project. Chris Baitz shared his past ROV experience and knowledge.

Dan Green for providing machining advice and experience to the design team and consulting on the gripper mechanism during the prototyping stage of this project. Graham Stewart for providing overwhelming support for the ROV team during the length of the project.

Table of Contents

Design Rationale

This section outlines how decisions regarding the manufacturing and assembly of Little Deep were made. All decisions were made in order to maximize the utility of this platform for shipwreck, scientific, and conservation related missions.

Concept Generation and Selection

The team conducted a rigorous concept selection phase which included creating detailed morphologies and decision matrices. These proved to be useful tools for narrowing the broad range of concepts down to a single best option for each component. Several functional and task oriented concepts were created in the morphology and then evaluated using the decision matrices.

The results of the selection process were determined by using a comprehensive team approach. The design team could not rely solely on the matrices for a final concept because some of the results were too close to be conclusive. Team discussions combined with input from our faculty advisor enabled the final decisions to be made in a timely manner. The following is a discussion of the final concept decisions of the functional and task specific requirements of the Little Deep ROV.

The concepts that were chosen directly from the matrices' results, due to a high score, are as follows:

- aluminum and polyethylene for frame material
- non-angled four thruster configuration for maneuvering
- side panel frame concept
- plastic pipe for electrical housing
- three camera configuration
- camera parallax for measurements
- air lift bag to retrieve anchor

The remaining possible concepts for the ROV required further discussion from the design team and advisor and were chosen as follows:

- combination of parallel gripper and suction cup to pick up objects
- fixed arm for simplicity
- air line buoyancy
- combination of mesh bucket and twist-closed punch

Working Prototype

In order to clarify the complex working prototype shown in Figure 1, this section will be expanded into the following five categories:

- Thrusters
- Frame
- Cameras
- Buoyancy, Tether and Electrical Systems
- Pneumatic Gripper and Gripper Arm
- Agar Sampler
- Conductivity Sensor
- Suction Gripper

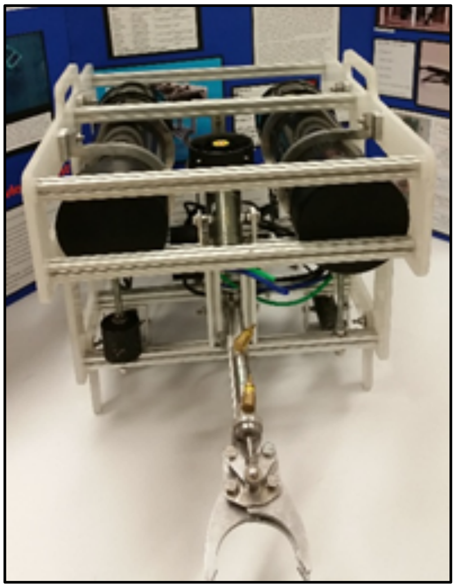


Figure 1. Full working Prototype

Thrusters

One of the first things the design team discussed was the thruster orientation they would be using on Little Deep. The design team decided to use a four thruster configuration, as shown in Figure 3, which includes two front and back thrusters, one vertical thruster and one lateral thruster. The four thruster configuration seemed to provide enough, if not more, maneuverability than would be needed to accomplish all the mission tasks. After deciding to use four thrusters, four Seabotix thrusters were chosen to propel Little Deep, providing a propulsion force of up to 25 Newtons each.

Frame

The very first thing the team had to design and build for Little Deep was the frame. There were several requirements that the successful design had to address. The frame had to be rigid enough not to flex when loads were applied and be made of corrosion resistant materials. Secondary priorities were that it be made of moderate density materials, to keep the weight down, and have as many quick mounting points as possible. As shown below in Figure 2, the frame for the ROV was water jet cut from two pieces of 3/8 inch UHMW polyethylene plastic, using BCIT's CNC water jet cutter. UHMW polyethylene was chosen for its durability, ease of machining, low cost, buoyancy characteristics, and aesthetic appeal. Extruded aluminum T-Slot was used for the cross members between side panels. T-Slot creates a strong and versatile platform that is easy to mount hardware to, with purpose built accessories or bolts shaped to fit. Little Deep's frame is like the foundation of a good house; a quality foundation holds the rest of the house together. Figure 3, shows Little Deep's frame fully assembled, including four thrusters.

Figure 2. Polyethylene side panel being cut to shape on a water jet cutter

Figure 3. Aluminum T-slot cross members with thrusters installed

Cameras

In order to accomplish all the mission tasks, a three-camera configuration was chosen, shown in Figure 4, with each camera outlined. Very durable and waterproof LCA 7700 underwater cameras were used with infrared technology in order to see within the dimly lit shipwreck. The upper camera provides a clear range of view of the gripper and agar sampler, while the two lower cameras provide a more comprehensive view of the environment directly in front of the ROV. The lower cameras also give the ROV the ability to use a method of parallax triangulation to gauge distances, to be used during the shipwreck dimensioning mission task. Custom camera mounts were constructed using square aluminum extrusion, which also serve a dual purpose as camera guards. The mechanism with which the cameras mount to the frame, allows mounting anywhere there is open T-Slot.

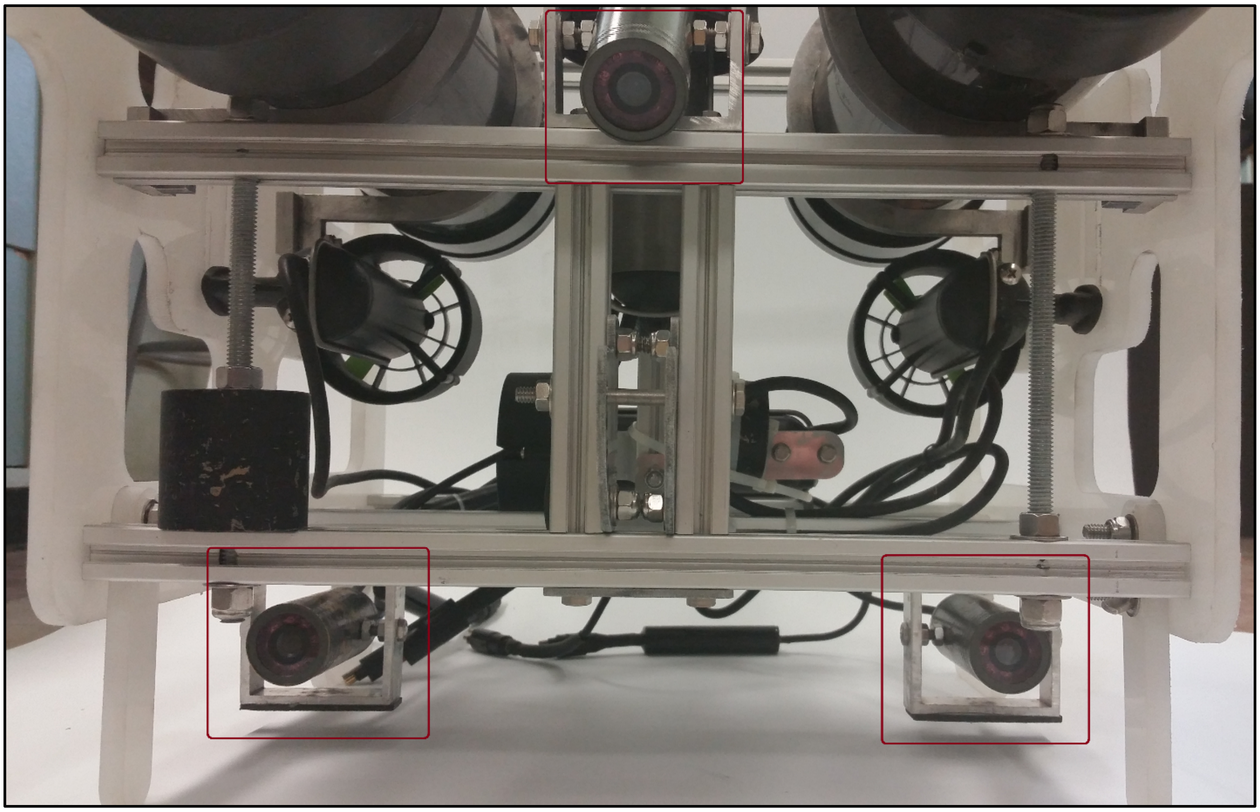


Figure 4. Camera layout, red squares emphasize camera positions

Buoyancy and Tether

One of the most challenging aspects of design for underwater applications is to make all the electrical connections completely watertight. For this reason, a large amount of time was spent rigorously waterproofing Little Deep's electronic's housing, which also function as the buoyancy tanks. These buoyancy tanks, shown below in Figure 5, play a dual role by providing a watertight environment and also providing buoyancy to bring the ROV closer to a neutrally buoyant state. The housings are made of ABS piping with one bonded end cap and one removable, three screw, end cap. Each housing provides approximately 8 kg of buoyancy and Little Deep required only a small amount of added ballast to achieve proper trim. Waterproof connectors were then mounted onto the removable end caps.

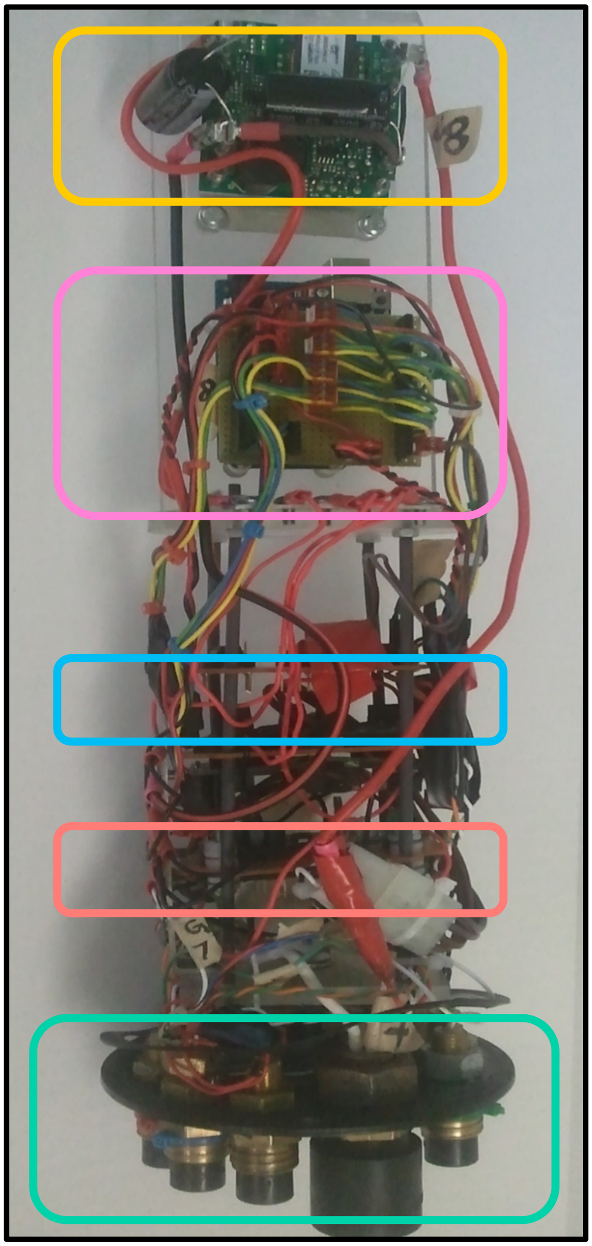
Figure 5. Dual bouyancy tanks

The tether consists of two category five cables for data transfer, one 12-gauge speaker cable for power, and pneumatic lines, each of which must be fully waterproofed. The two pneumatic lines serve as buoyancy for the tether and keep the entire length roughly neutrally buoyant, while maintaining a sleek, tangle resistant profile.

Electronics Tray

The electronics tray, shown below in Figure 6, is mounted within the watertight electronics housing. Three different voltage levels are present: a Lineage Power step-down DC-DC voltage converter supplies the four Pololu motor controllers with 19.1 Volts, an un-modified Texas instruments LM5575 provides a filtered 5 Volts for the digital control, and a modified Texas Instruments LM5575 provides 12 Volts for the video cameras and the bilge motor.

The onboard Arduino Uno interfaces with two MAX485 ICs in a full-duplex configuration, allowing simultaneous transmit and receive operations.



Voltage Regulator
Provides 28 volt power for thrusters

Arduino Uno with Removable Shield
Communicates with surface Arduino, delivers commands to motor controllers, Controls ROV

Motor Controllers
Control speed and direction of thrusters

Voltage Regulators
Provide power to Arduino and cameras

End Cap
Enables waterproof housing for electronics

Figure 6.Electronics tray which controls the various functions of the ROV

The Gripper

The gripper and gripper arm assembly, shown below in Figures 7 and 8, were modeled with Solidworks 2014 and were designed to provide the maximum gripping force from a one inch stroke cylinder. After finishing the model, the gripper files were sent to BCIT's top of the line water jet cutter, and all of the parts were accurately fabricated. The gripper was designed with a radial claw to allow for cylindrical objects to be easily gripped. It also features a serrated edge at the very tip of the claws to allow for pinching of thinner objects. The gripper uses pneumatics to actuate the gripping mechanism and is controlled by the pilot with a manual valve on the surface.

Figure 7. Gripper Unassembled

Figure 8. Gripper Assembled

Agar Sampler

Little Deep has an optional core sampling attachment that allows for soil or sludge sampling up to 150 ml at a time. The sampler was fabricated using 6061 aluminum with custom brass directional fins for sample retention, as shown in Figure 10. The unit is mounted to a short section of T-slot extrusion, which allows for quick and easy mounting to the frame of the ROV.

igure 9. Optional core sampling attachment

Conductivity Sensor

In many circumstances, it is beneficial to accurately determine the conductivity of the marine environment. Shown in Figure 11, Deep Robotics has developed a lightweight quick connect conductivity sensor, called The Proboscis, that can be attached to Little Deep's frame. Two parallel conductive plates measure the resistance of the saltwater, which can then be converted into a conductivity value. The sensor comes with a perforated PVC guard to protect the sensitive electrodes from impact.

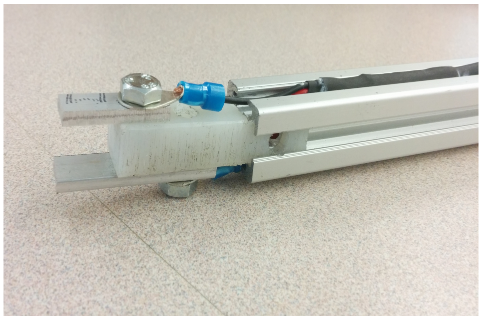


Figure 10. The Proboscis conductivity sensor with protective shroud removed

Suction Gripper

In order to expand the range of objects that Little Deep is capable of manipulating, a suction gripper has been designed and included with the Little Deep package, as shown in Figure 12. The suction is powered by a small but reliable 12 Volt UltraSump pump. Using off-the-shelf components, the inlet of the pump is drawn through several fittings with a suction pad to allow for manipulation of objects even when at undesirable angles. Using a combination of pneumatic tubing and T-slot, the suction pad can be located anywhere on the ROV that is required for any situation; all without requiring the pump to be relocated.

Figure 11. Suction gripper for hard to grab objects

Cost Analysis

In this section, a breakdown of the cost of manufacturing the Little Deep ROV is presented.. Shown in the following tables are the costs of this project:

Materials					
#	**Description**	**Supplier**	**Qty**	**Cost**	**Incurred Cost**
1	T-Slot (w/connectors)	Surrey Fluid Power Ltd.		70.00	70.00
2	Polyethylene Side Panels	BCIT		30.00	0.00
3	Thrusters (Seabotix)	BCIT	4	4000.00	0.00
4	Cameras (LCA 7700-CW)	BCIT	3	2700.00	0.00
5	Pneumatic Actuator	BCIT	1	25.00	0.00
6	Pneumatic Air Lines	BCIT	1	15.00	0.00
7	Pneumatic Compressor	BCIT	1	150.00	0.00
8	Pneumatic Valve	BCIT	1	75.00	0.00
9	Aluminum (gripper, brackets)	BCIT		50.00	0.00
10	Miscellaneous (bolts, washers)	Pacific Fasteners Ltd.		60.00	60.00
11	Dry boxes (ABS)	Home Depot		95.00	95.00
12	Arduinos	Lee's Electronic Components Ltd.	2	60.00	60.00
13	Motor Controllers	Lee's Electronic Components Ltd.	4	120.00	0.00
14	48 to 28 step down	Lee's Electronic Components Ltd.	1	70.00	70.00
15	48 to 12 step down	Lee's Electronic Components Ltd.	1	30.00	0.00
16	48 to 5	Lee's Electronic Components Ltd.	1	30.00	0.00
17	Joystick	BCIT	2	40.00	0.00
18	Wires	BCIT		20.00	0.00
19	Electrical wire 12 gauge	RP Electronics Ltd.	1	75.00	75.00
20	Waterproof Connectors	BCIT	10	1000.00	0.00
22	48 Volt Power Supply	BCIT	1	50.00	0.00
	Total Cost of Materials			**$8,765.00**	**$420.00**

Travel Expenses			
#	Destination	Reasoning	Cost
23	Seattle	Qualifying Round	400.00
24	Michigan	International Competition	9600.00
Total Travel			**$10,000.00**

Projected Labour				
Based on technologist wage at $22.00 per hour				
#	Phase	Number of Technologists	Hours per Technologist	Cost
25	Pre-design	5	60	6600.00
26	Design	5	100	11000.00
27	Post design	5	140	15400.00
	Projected Labour Total			**$33,000.00**

Incurred Cost		
#	Description	Cost
29	Materials	420.00
30	Travel	0.00
30	Labour	0.00
Incurred Total		**$420.00**

Overall Total		
#	Description	Cost
31	Mechanical	7260.00
32	Electrical	1505.00
33	Travel	10000.00
34	Projected Labour	33000.00
Overall Total		**$44,505.00**

Safety

At DEEP Robotics, safety is a top priority. This attitude is incorporated into everything from the design, manufacturing, and operation of the ROVs.

The electrical systems have been equipped with a 20-amp breaker at the top surface to act as a disconnect between the shore power and the ROV in the event of a circuit overload or fault. Another feature of the electrical system is the instantaneous stop of thrust if power is lost. This enables the ROV to passively rise to the surface due to the slight positive buoyancy implemented by the design team.

The frame has been designed with an internal thruster configuration that protects the thrusters from unintentional contact with the underwater environment. Each self-guarded thruster is equipped with safety warnings. The frame has also been designed with the safety of the operating crews in mind. Each side panel was manufactured with rounded corners and carrying handles, allowing for ease of transportation, launch, and retrieval of the vehicle.

During manufacturing, the employees follow strict rules to ensure the safety of themselves and the people working around them. Approved safety goggles, footwear, and hearing protection were worn at all times during the construction and assembly of the ROV.

Before every expedition, an above water test is performed. This consists of assuring the manipulator, thrusters and cameras are working properly to reduce the risk of an underwater failure.

The tether is a crucial set of components in the ROV system. It is the lifeline that facilitates communication between the operators on the surface and the underwater vehicle. Certain protocols have been put in place to ensure the longevity of the life of the tether.

A tether manager will be assigned to the ROV before every expedition. The tether manager is responsible for the care and maintenance of the tether during expedition set up, vehicle launch, mission execution, and vehicle recovery.

The tether consists of power cables, communication cables, and pneumatic lines. To aid in the protection of these components the tether has been surrounded by a sheath. This enables the tether lines to be held together as if they were one unit. During expeditions, the tether will be secured to the central control station on the surface, separate from the vehicle controller. The design team has taken this precaution in order to prevent the communication lines from being separated from the controller if the tether was to exceed its maximum length.

Challenges

Throughout the duration of this project many challenges were encountered and overcome. Although they affected the timeline of the project, the learning outcomes were of significant value.

Some of the challenges that were faced during this project were the following:

- **Time** – Because the project had such a short time frame, many design concepts had to be changed.
- **Communication –** Communication became key between all members of the team especially between the mechanical students and mechatronics student.
- **Integration –** The team hadn't put aside enough time for the integration of mechatronic components.
- **Waterproofing –** The process of waterproofing, heat shrinking and sealing countless wired connections was not only a time consuming process but had to be done correctly in order to avoid future problems.

Figure 12. DEEP Robotics at the Northwest Regionals in Federal Way, Washington

Lessons Learned

The design team accepted the challenge of this project with great enthusiasm. The team understood that because of the scope and complexity of the project, many obstacles would need to be overcome.

The most resonating lesson the team learned from this project was the importance of good communication. This was especially true during integration of the mechanical and mechatronics systems. As deadlines approached, the interaction between the engineering disciplines increased significantly and it became apparent that communicating effectively was essential to realizing their goals.

A very common characteristic of project work is the concept of iteration. Iteration of the design and construction phases happened for many different reasons. As learned in the MECH 4490 project course, failing early and failing often is usually considered advantageous. An example of this was when the buoyancy tank design changed while still in the design stage. The team decided two smaller diameter tanks of ABS plastic would be beneficial over one larger diameter tank. Once in the fabrication phase making this change could have resulted in wasted material. The unnecessary material would have consisted of more than just what the design called for, as the minimum purchasing order amount of the larger diameter material was several times the amount needed.

Effective time management is another aspect of the design process that the team felt was a great lesson learned. It became obvious early in the project that the timeline and due dates would require close attention.

The members of the design team felt it was important to complete this project to a high standard. Even with all team members sharing this attitude, it became apparent that compromise would need to happen. It is important to understand when enough is enough, for instance, when machining to tight tolerances is not necessary. If the function of the part being fabricated isn’t affected by the looser tolerances and esthetic requirements are met, then resources might be better allocated elsewhere. An example of this was in the fabrication of the camera mounting brackets and electronic tray.

A version of the 80/20 Rule, which was coined by Vilfredo Pareto and touched on by the team’s supervisor, Taco Niet, seemed to ring true. It essentially states that 80% of the work is completed with 20% of the effort and the last 20% of the work requires 80% of the effort. The team saw this when integrating the electronics and programming into the mechanical system and approaching the deadline for the international competition qualifier.

Future improvements

DEEP Robotics strives to continually improve its product. In order to increase the working potential of this ROV a list of future work to be performed has been compiled. The design team can complete these future tasks in order to increase the potential customer base and functionality of the ROV. The improvements are as follows:

- **Incorporate an Onboard Solenoid Valve** - Would result in an increased response time for the gripper as well as simplifying the control inputs to be totally electronic.
- **Redesign the Electrical Tower -** Simplifying multiple components onto a single circuit board would reduce the required space and, due to less clutter, increase reliability and simplify troubleshooting.
- **Incorporate Position Feedback** - Including this feature in the control system would allow for more precise maneuverability and allow the ability to preprogram and automate specific pathways.
- **Incorporate Active Buoyancy -** This would increase payload capacity and vehicle trim while eliminating the need for an external lift bag.
- **Add a Joint to Gripper Arm -** Would allow on-the-fly angle adjustment of the gripper to increase manipulation ability.
- **Digitize the Camera Signals -** Would allow a reduction in the number of cables that run up the tether.

Reflections on the experience

The DEEP Robotics team would like to thank the MATE organization for facilitating this extremely valuable learning experience. The learning outcomes and realizations that were achieved throughout this project are many and diverse; we will expand on some of the most valuable, below.

Prior to starting this project, none of the team members had any experience whatsoever in the underwater ROV field. This resulted in a very steep learning curve and instilled in many of us a passion for a subject that we hadn’t even considered largely in the past. Not only is underwater robotics a very interesting and hands on field, but the industry is booming with exciting job prospects, something which is always an important consideration for soon to be technologists.

It goes without saying that the design and fabrication experience gained during this project will be very valuable during any future academic pursuits and even more so when making the transition into industry. School gives you a few tools to use but you don’t really learn how any of them are actually used until you take on a project like this. One of the most rewarding parts of the competition was experiencing the buzz and excitement of the Pacific Northwestern Regional Competition in Federal Way, Washington. Watching the Scout, Navigator, and Ranger classes display their achievements and innovations with enthusiasm was very rewarding, after all, these are the future generations that the TBNMS is striving to protect the environment for.

References

The design team has required a significant amount of resources to develop this project. The following is a list of essential resources for this project:

BCIT Faculty

- Taco Niet, P.Eng – Project advisor and sponsor
- Brent Dunn, P.Eng – Mechatronics program head

Research

- MATE – ROV competition manual, published textbook " Underwater Robotics – Science, Design & Fabrication"
- BCIT Library – Patent, journals, articles, engineering textbooks, ROV textbooks
- Online – Patent searches, articles, journals, forums
- International Submarine Engineering – Tour of facilities, primary research

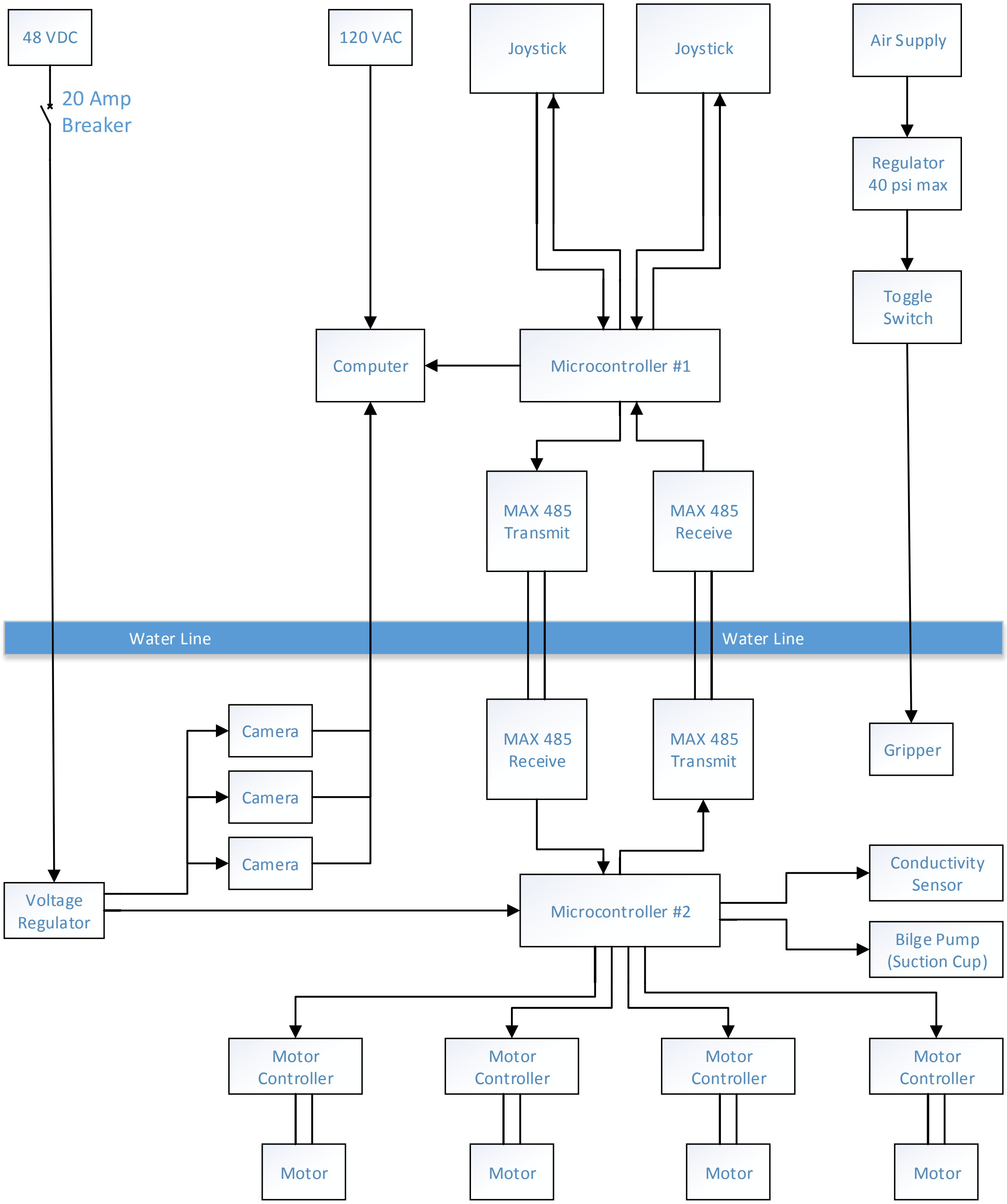
Software

- Solidworks 2014 - 3D modeling, analysis, and simulation software
- Autodesk 2014 – 3D modeling software
- Dropbox – Online storage and file sharing for team members
- Microsoft Office – PowerPoint presentations, word processing and documentation, Excel for spreadsheets data tables and graphs.
- CES database – material selection
- Maple 17 – Mathematical software

Manufacturing and Testing

- Machine shop – CNC, lathes, water jet cutter
- Plastics lab – epoxy, fiberglass, vacuum thermoforming
- Robotics lab – wiring and programming
- Electronics lab – circuit board construction
- Project lab – storage, assembly
- Design lab – computer access

Systems Interconnection Diagram



Flow Charts

Surface Module Code

Little Deep is remotely operated from the surface through a tether connected to a control box. Inside the control box an Arduino Mega is interfaced to the tether through a full-duplex EIA-485 communication configuration and to the laptop computer via a USB cable.

The two dual-axis joystick inputs are read and converted to control data containing direction and pulse width modulation values for the four thrusters. Little Deep has two operating modes, DEFAULT and SPIN, selected by a push button mounted on the control box. The DEFAULT mode uses the right hand side (RHS) joystick to propel the ROV using a vector algorithm while the left hand side (LHS) joystick controls the vertical thruster and the lateral thruster. When the operator enters the SPIN mode the lateral thruster speed is cut, the vertical thruster speed enters cruise control and the RHS and LHS joysticks control their respective forward/reverse thrusters.

The LHS joystick push-button controls the bilge pump operation, and the RHS joystick push-button controls the conductivity sensor.

The control data is then packaged between pre-determined ‘start’ and ‘stop’ bytes to ensure data fidelity and transmitted to the ROV Module.

A sensor data package is then read from the ROV Module and checked against pre-determined ‘start’ and ‘stop’ bytes. If the sensor data package contains the properly placed, pre-determined bytes, fidelity is assumed and the sensor data is read and then transmitted to the laptop computer via the USB cable.

ROV Module Code

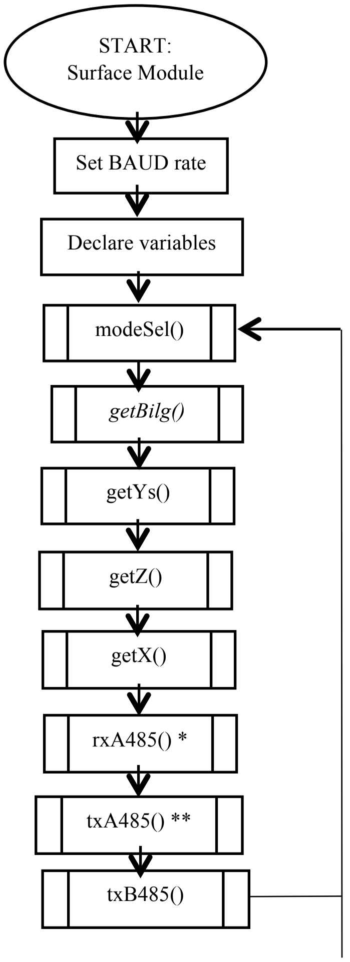
Little Deep is controlled at depth by an onboard Arduino Uno connected to the Surface Module through a tether. The Arduino Uno is interfaced to the tether through a full-duplex EIA-485 communication configuration.

A control data package is read from the Surface Module and checked against pre-determined ‘start’ and ‘stop’ bytes. If the control data package contains the properly placed, pre-determined bytes, fidelity is assumed and the control data is read and used to control the four thrusters via the motor controllers, the bilge pump through its control circuit, and the activation of the conductivity sensor.

When activated, the conductivity sensor performs a measurement and is then packaged between pre-determined ‘start’ and ‘stop’ bytes to ensure fidelity and transmitted to the Surface Module.

Main: Surface Module

This sketch reads the joystick control inputs, transmits the data to the ROV Module, receives conductivity sensor data from the ROV Module and displays the value on the computer screen.



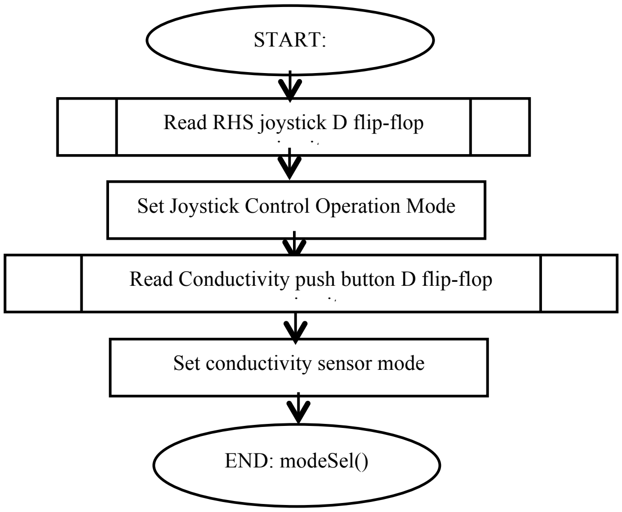
NOTE:

*The structure of rxB485 is similar to the structure of rxA485

**The structure of txC485 is similar to the structure of txA485

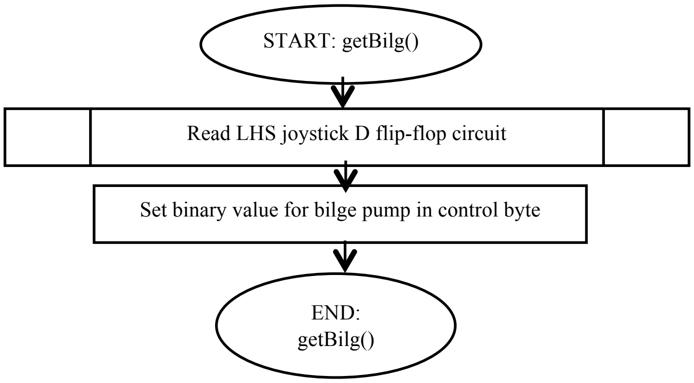
Subroutine: modeSel()

This subroutine reads the status of the mode select push-button and the conductivity push-button and sets the operation mode and sensor read mode.



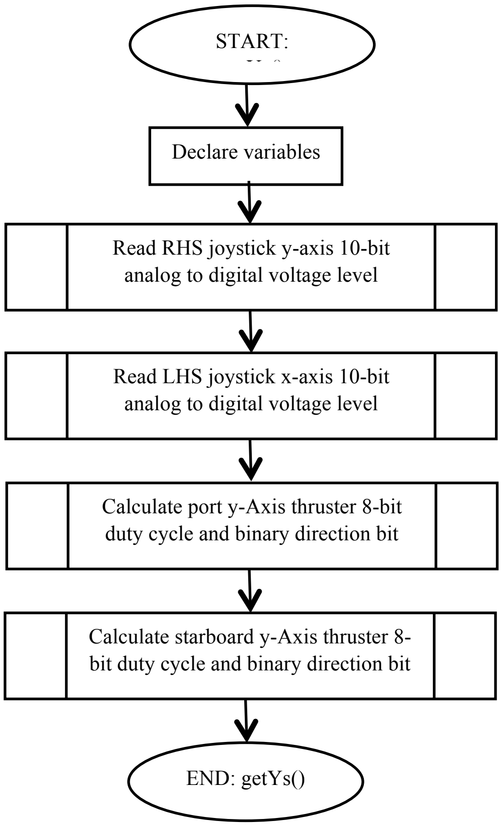
Subroutine: getBilg()

This subroutine reads the status of the bilge pump push-button and sets the bilge pump control bit.



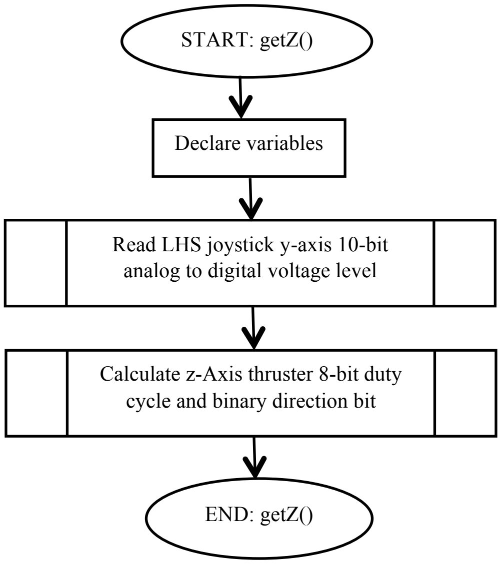
Subroutine: getYs()

This subroutine reads the analog values on the RHS joystick and calculates the PWM value and the direction for both y-axis thrusters.



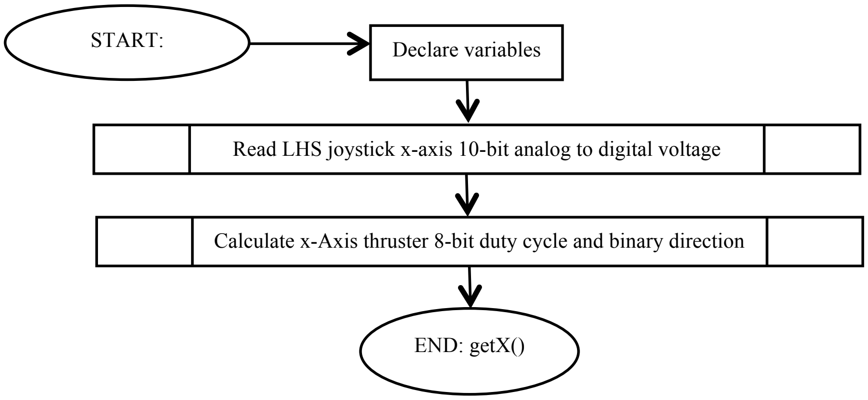
Subroutine: getZ()

This subroutine reads the analog values on the y-axis of the LHS joystick and calculates the PWM value and the direction for the z-axis thruster.



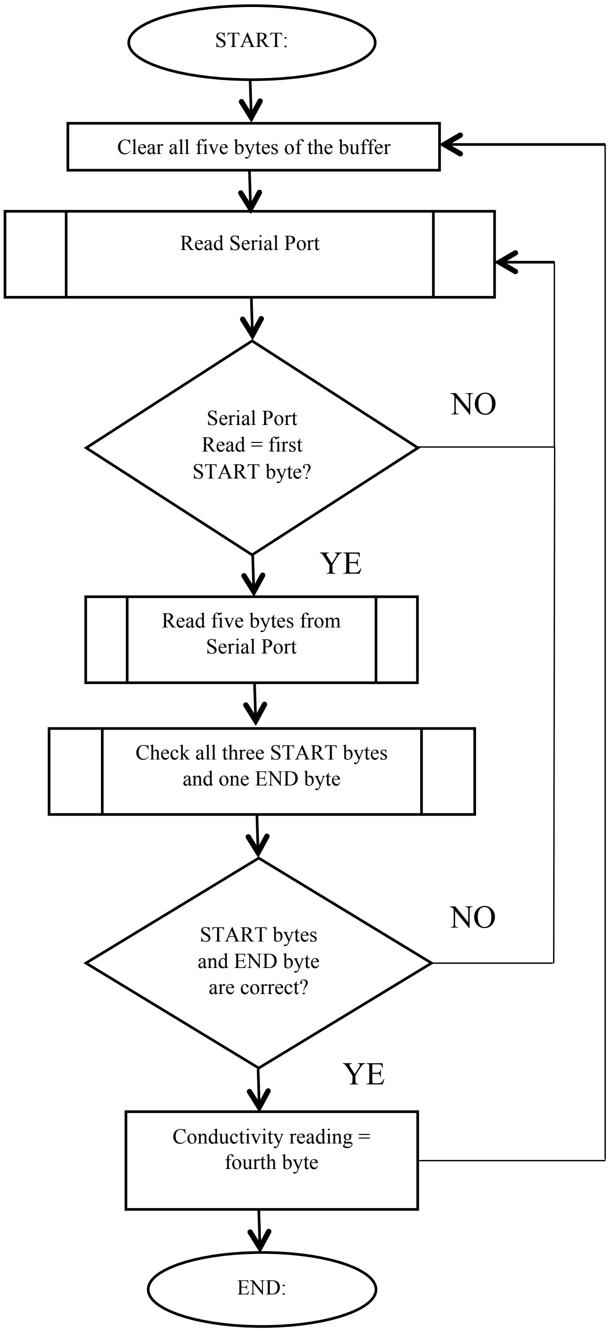
Subroutine: getX()

This subroutine reads the analog values on the x-axis of the LHS joystick and calculates the PWM value and the direction for the z-axis thruster.



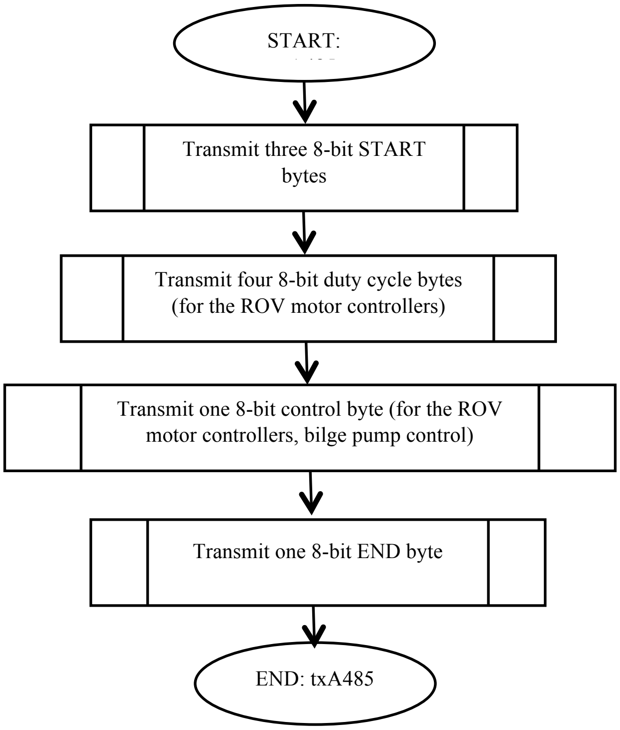
Subroutine: rxA485

This subroutine reads the conductivity sensor data sent from the ROV Module.



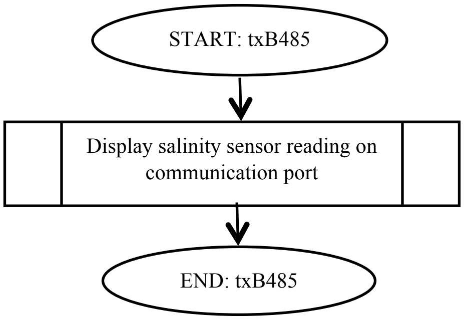
Subroutine: txA485

This subroutine sends the motor control data to the ROV Module.



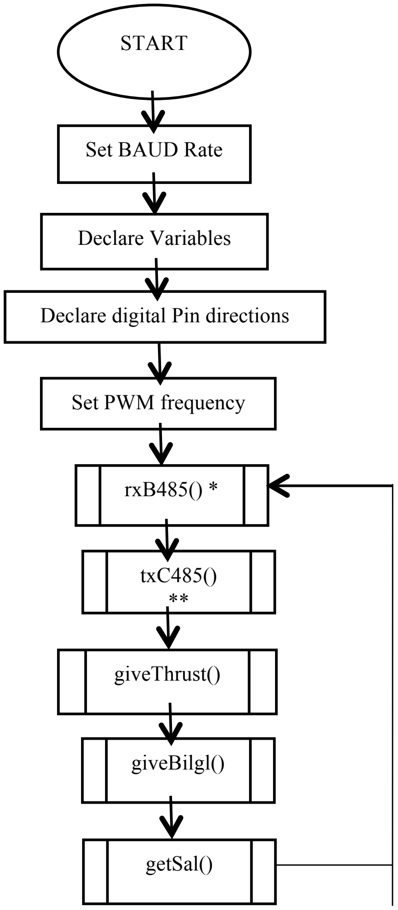
Subroutine: txB485

This subroutine prints the conductivity reading to the computer screen.



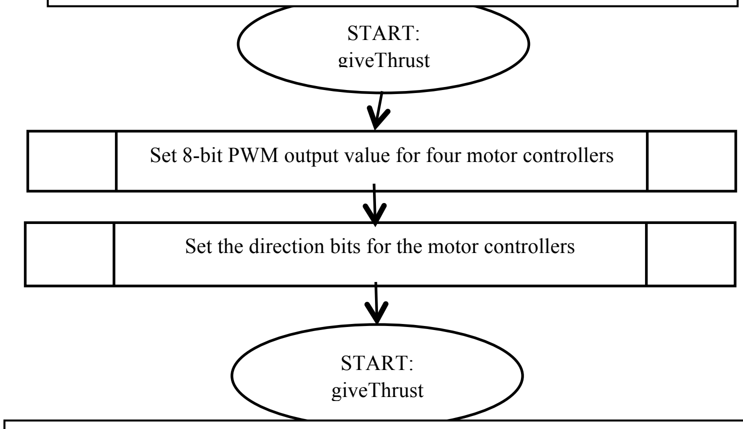
Main: ROV Module

This sketch reads the conductivity sensor, transmits the data to the Surface Module, receives control data from the Surface Module and controls the motor controllers and the bilge pump.



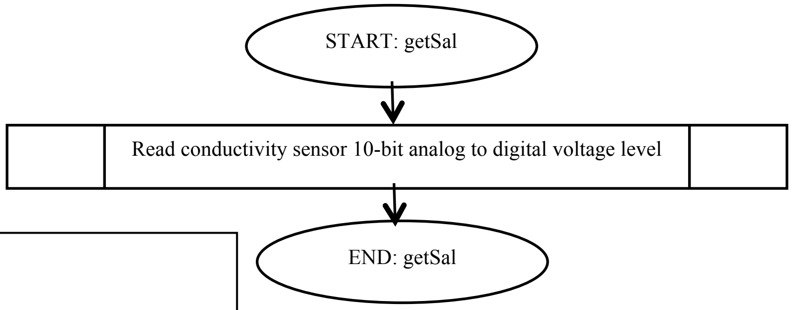
Subroutine: giveThrust()

This subroutine drives the four motor controllers.



Subroutine: getSal()

This subroutine reads the conductivity sensor.



Subroutine: giveBilg()

This subroutine controls the voltage level on the bilge pump circuit.