The Dalhousie Privateers

DAL ROV

Dalhousie University, Halifax, NS, Canada
2012 MATE International ROV Competition

Explorer Class

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Abstract

This report documents the Dalhousie Privateers' entry for the 2012 MATE International ROV competition. The report details how the team consistently followed a *tools-first* design approach for efficient mission completion, while also focusing on overall reliability. The team continues to take pride in designing, constructing, programming and testing as much of the craft as possible to create a customized solution that is not possible with off the shelf parts.

The craft is driven by a set of eight variable speed custom designed thrusters. Four thrusters arranged in a vector arrangement provide the craft's lateral movement, while another four thrusters move the craft vertically.

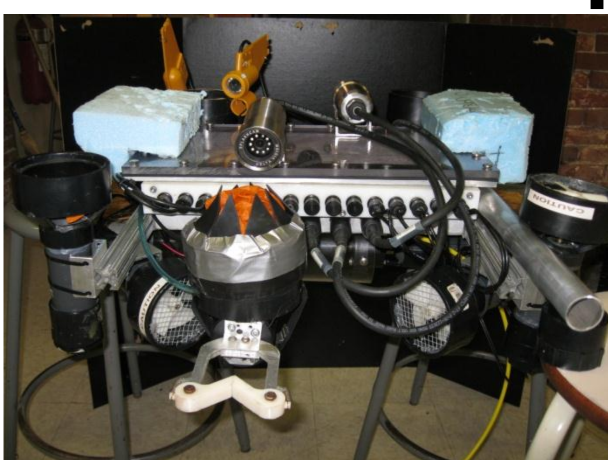
The ROV features custom tools, tailored to the needs of each individual mission to complete each task as quickly and efficiently as possible. A rigorous testing routine was used to ensure tool effectiveness.

Onboard electronics are housed in an aluminum casing. These interface with a portable command center for controlling the ROV and displaying video feeds at the surface.

The modular aluminum frame was designed around the aforementioned components and has as little wasted space as possible, with a shape that optimally positions the tools to complete the mission tasks. The frame is entirely based around the central electronics box with multiple universal ports for power connections. These were designed to avoid splicing wires outside of the electronics box, which has proven unreliable in the past.

It is with great pride that the Privateers introduce their fifth generation ROV:

The μ-Boat



1. The Dalhousie Privateers

The Dalhousie Privateers follow a relatively simple company structure designed to aid the company's dual purposes: the development of quality ROVs and the continual training of members. ROV design is broken down into subtasks (mechanical, electrical, and administration), each of which is headed by a team leader selected for experience, leadership, and interest in that subtask. The team leader is responsible for guiding the development of their subtask and for ensuring their team members follow responsible, safe building practices. They are also responsible for holding skills training sessions to aid members in developing related technical skills. The team leaders report to the company CEO, whose responsibilities include organizing team leader meetings and developing the technical and leadership skills of the team leaders. At the team leader meetings, the project's progress is reviewed in relation to the schedule set at the beginning of the year to ensure its timely completion.

Figure 1 Company Photo

2. Product

Since the company's creation, the Dalhousie Privateers have endeavoured to provide high quality ROVs, tailored to each client's specific needs. All vehicles that leave our workshop are outfitted with unique tools, customized to perform the client's tasks with the utmost precision and efficiency.

2.1. Facilities

The Privateers' main facility is a dedicated workshop for ROV construction, pictured in Figure 2. The workshop is outfitted with a full range of handheld tools, multiple soldering stations, and several bench tools, including a band saw, drill press, and belt sander. The shop is well stocked with safety gear, including protective glasses and ear protectors. Cleanliness and organization are widely practiced by our workers for increased safety practices. The workshop is also outfitted with a large tank, approximately 1.5 m deep and 2 m in diameter, used for testing prototypes in water. For testing at a greater depth, the team uses the Aquatron, a 10.3 m deep aquatic research facility generously provided by the Oceanography Department at Dalhousie University.

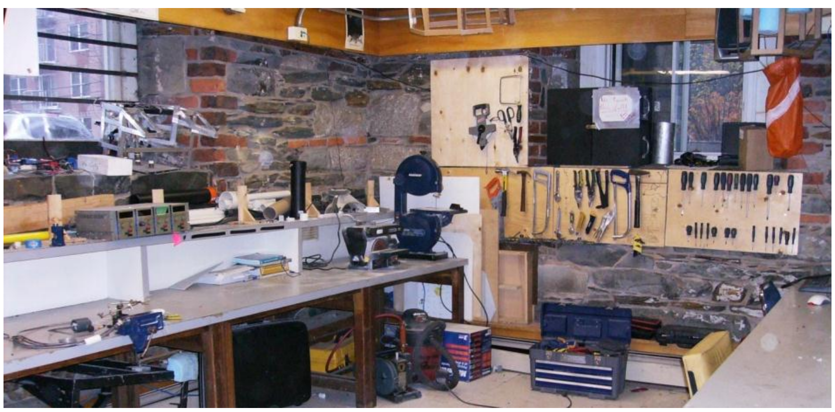


Figure 2 Privateer's workshop

2.2. Design Rationale

The company policy at Dalhousie is to build a new craft every year. The team builds a new craft each year for two main reasons: to offer a complete experience for new employees and to develop unique ROVs that are tailored both for the current tasks and to improve from previous models. Because of this, the company has a portfolio of highly trained capable workers with unique state of the art ROVs. This year, the team took extreme care to develop a reliable ROV with a modular frame, wiring and robust cameras and tether. The team chose to focus on these specific areas due to failures suffered by ROVs from previous years.

2.3. Safety

Safety is the foremost concern of the company, both during manufacturing and operation of the ROVs. Several protocols are enforced in the team's workshop to ensure employee safety. The first is the use of safety glasses and other personal protective equipment while in the workshop. The second is the requirement for all new members to be trained in using the workshop equipment. Such training includes an introductory tour by faculty supervisors, and then training and practice on the equipment. The shop is also kept clean and organized, with all exits kept free from obstacles and tools returned after use. The last person in the workshop is tasked with making sure all electrical breakers are locked and all tools are unplugged and stored in their respective spots. When deploying, operating, and retrieving the ROV, a safety checklist is rigidly followed along with all other safety practices at the corresponding location (personal flotation devices required, lifeguards on duty, etc.). These safety practices and designs allow our company to have a safe work environment and to develop safe products.

2.4. Company Budget

Table 1 shows the cost breakdown of the team for 2011-2012. The budget was submitted for approval to the Dean of Engineering at Dalhousie University on September 11, 2012. The actual cost of the items is shown as well as the difference.

Table 2 shows the company's income (via donations and sponsorship). Please note that of the $9,200 surplus, $1,800 dollars has been spent on upgrades to the team's work space. The remainder of the surplus will be used for future years.

Table 1 Operating Budget

Dal ROV Budget 2011-2012

Updated 8-May-12

Item	Budget	Cost	Difference
Construction			
Electronics (boards, components, etc.)	$1,500	$2,720	-$1,220
Materials (plastics, steel, etc.)	$800	$246*	$554
Cameras	$2,130	$2,399	-$269
Tether	$200	$257	-$57
Rapid Prototyping (material)	$325	$52*	$273
MATE mission props construction	$500	$334	$166
Motors & Actuators	$500	$300	$200
Payload Tools	$600	$400	$200
Construction Subtotal	**$5,955**	**$6,708**	**-$753**
Travel	**-**	**-**	**-**
Air Fares	$7,500	$2,400	$5,100
Room & Board	$4,000	$2,717	$1,283
Transportation	$1,400	$2,500	-$1,100
Travel Subtotal	**$12,900**	**$7,617**	**$5,283**
Total	**$18,855**	**$14,325**	**$4,530**

Market value of donated materials *

Table 2 Company Income

Inflow	Amount
Dalhousie University	$8,000
Ultra Electronics Maritime Systems	$5,000
Shell Canada	$5,000
EnCana	$1,000
Akoostix	$1,000
Engineers Nova Scotia	$600
DSU	$250
ADM Systems Engineering LTD	$200
Dalhousie Mechanical Engineering Department	$325
Stantec	$300
Mariner Forge Enterprises	$150^
Jentronics	$80*
** = donation of electrical equipment*	
^ = donation of materials	
Other	
Surplus from 2010-2011	$995
Team Travel Contributions	$700
Total	**$23,600**
Surplus	**$9,275**

2.5. Product Development Timeline

The company developed a timeline, shown in Figure 3, at the beginning of the year and tried to adhere to it for proper development phases. The deadlines were based on ones made in previous years, with some adjustments for desired areas of focus. Some changes to the schedule were needed as the team advanced through development of the ROV.

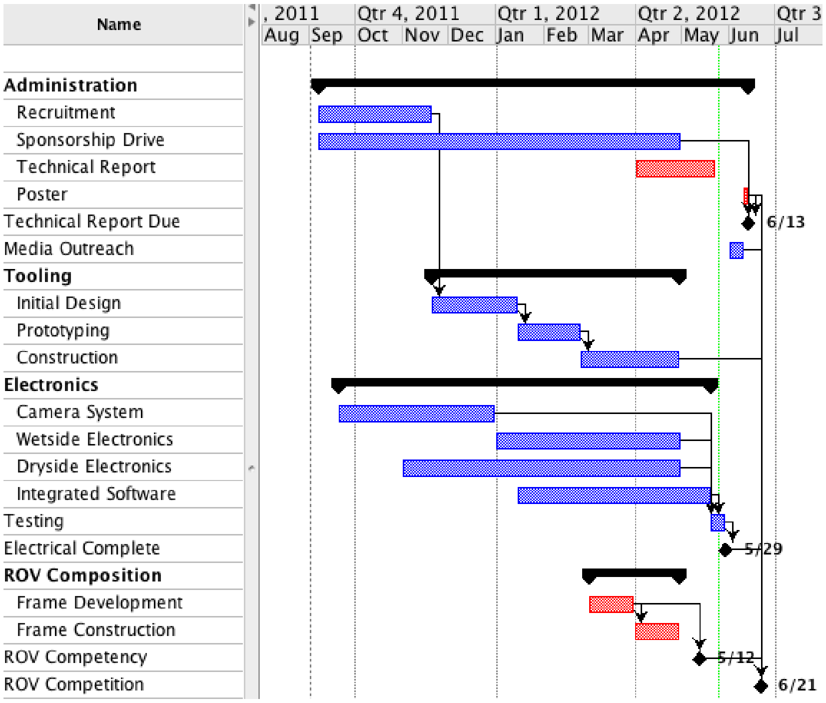


Figure 3 ROV development timeline

3. Development of the *µ-Boat*

3.1. Mini ROV

To have an effective tools-first design strategy, a method of testing individual tools under realistic operating conditions was required. Last year, the team implemented a very successful strategy to test tools by using a Mini ROV. The Mini ROV was used to test prototype components to ensure that they would work at depth and to troubleshoot potential issues as early as possible. It was instrumental in comparing the effectiveness of tool prototypes and ensuring the performance of other components such as the propulsion system and cameras.

In order to introduce new members to the design process quickly, the team split them into two main focus groups headed by the electrical and mechanical training leads. These focus groups were tasked with designing and constructing a new Mini ROV. The training continued from September through November, and was much more detailed than in previous years.

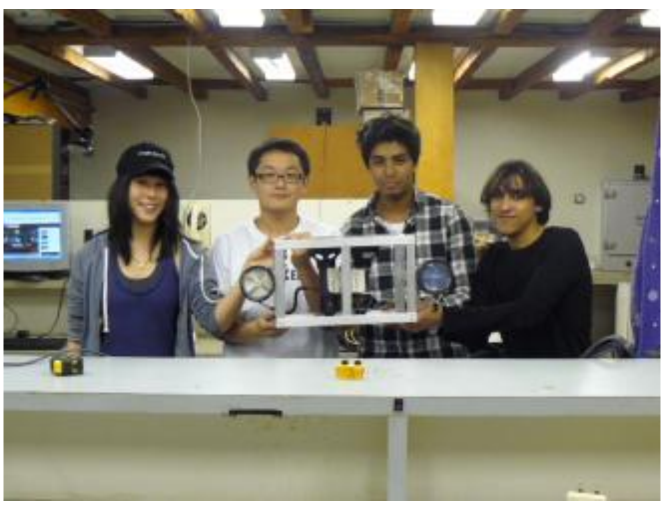


Figure 4 Mini ROV with new team members

The training leads designed programs that would best suit their mechanical or electrical sub-groups. While the mechanical members immediately began brainstorming ideas for the frame and buoyancy, the electricals first built miniature robots that could follow a line. By building the robots, the electricals were taught safe and proper soldering techniques, as well as how to read circuit schematics. They also learned how electrical components such as phototransistors and capacitors work. This gave the mechanical team time to design and build a frame and buoyancy for the Mini ROV (pictured in Figure 4). While building, they were taught how to safely use the power and hand tools in the lab, and gained an understanding of what it takes to construct an underwater vehicle. Once the mechanicals had mounted previous years' thrusters to the frame, the electricals built a switch box with which to drive the craft.

3.2. Payload Tools

Unlike in previous competition entries, this year there are only two mission tasks. However, these tasks are broken into several smaller subtasks, requiring the team to develop nine tools.

3.2.1. Ship Measurer

The ship measurer is designed to measure the length of the sunken ship as the ROV drives once along it. Several ideas were prototyped; the most effective was a commercial tape measure. A triangular clip at the end of the tape slips over the ship's bow, after which the ROV spools the tape out as it drives, viewing the measurement with a camera aimed at the tape.

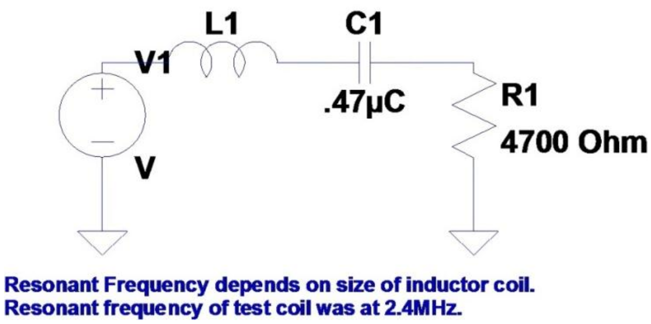


Figure 5 Metal Detector

3.2.2. Metal Detector

The team opted to use a resonance circuit to detect the shipwreck debris. A coil is made so that it slides over the metal debris whose iron core drastically changes the coil's inductance, unbalancing the circuit. A schematic is shown in Figure 5.

3.2.3. Scanning

In order to scan the ship, the ROV was fitted with high quality cameras, and one high-intensity light. For more details on cameras, please consult Section 3.6.1. For discussion of the operation of the high intensity light, please consult Section 3.6.

3.2.4. Compass

A compass is mounted at the stern of the vehicle with a camera in view to determine the ship`s heading. The compass can be calibrated to match the heading specified at the competition site. The team tested the compass to determine if the electronics would interfere with the readings, and no adverse effects were found.

3.2.5. Mast Lifter

In order to move the fallen mast, the ROV needs to complete three sub-tasks:

- Attach to mast U-bolt
- Lift mast with aid of a floatbag
- Disconnect mast from vehicle

Accordingly, the tool has three modules:

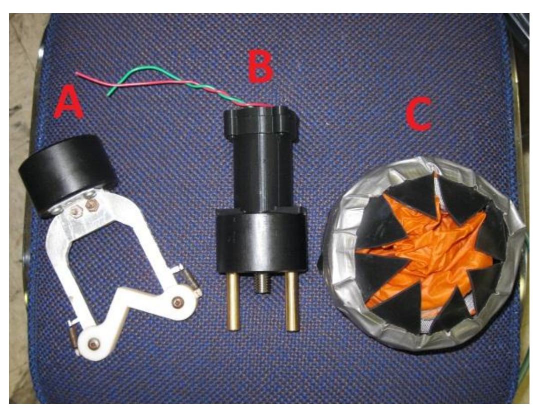


Figure 6 Mast Lifter parts

U-bolt Clip (A):

The design of the mast attachment tool, depicted in

Figure 6, was inspired by carabiners. The tool has a pair of spring loaded jaws which open in only one direction. These passive jaws open easily to clip on to the mast U-bolt, and will not slip off afterwards.

Floatbag (C):

The Privateers opted to create their own float bag, because after testing the one offered by MATE, they found that it could not be packed compactly enough. Our light bag is folded and tucked into a canister with an air hose that runs to its top. When air is let in from an onboard 1 L 275 kPa tank, the bag deploys from a canister. For safety, the bottom of the bag is open so any excess pressure can escape. Compressed air is in a container with fittings rated 2.5 times higher than the relief valve, which is set at 2.75 kPa (40 psi).

Disconnector (B):

The entire U-bolt Clip and float bag assembly is mounted on sliding shafts held in place with a threaded rod. Once the mast has been transported to its final location, a high torque motor turns the threaded rod, turning it into a power screw that pushes the rest of the tool, attached to the mast, off the ROV. The airline from the onboard tank to the float bag is connected via spigots, from which the airline is forced when the power screw engages.

3.2.6. Coral Grabber

Given the simplicity of removing coral from the ship hull, the emphasis for this tool was on speed and ease of use. A four-bar mechanism was designed, which uses the linear motion from a commercial power door lock actuator to open and close a simple gripper. As illustrated in Figure 7, the gripper is shaped to close around the thinnest part of a coral stem, and provide a secure hold once the gripper closes. Two identical Coral Grabbers were installed on the ROV, one each on the forward port and starboard. This allows the pilot to pick up both corals and transport them at once, without having to make multiple trips to the ship.

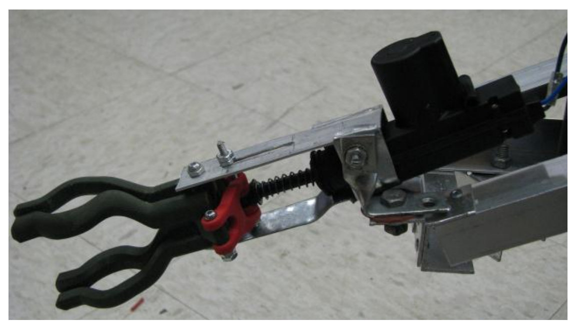


Figure 7 Coral Grabber

3.2.7. Calibration device

The calibration device is a 15 cm long by 3.5 cm outer diameter aluminum pipe. This device is used for both the neutron back scatter and thickness gauge sensor devices.

3.2.8. Oil Puller

The single most important mission task is removing oil from the sunken oil tank. In order to successfully complete this task, the oil puller tool must accomplish three separate actions.

- Mate with the tank interface and penetrate a petroleum jelly barrier

- Withdraw oil from the tank
- Fill the tank with salt water

It was identified from an early stage that the first task would require a separate tool module, called the oil tank connector. The oil tank connector is entirely passive, to increase reliability. As seen in Figure 8, the oil tank connector features twin sockets, spaced to fit loosely over the two openings to the oil tank. The sockets are flared at the bottom to help the pilot align them over the oil tank openings. A plastic tube protrudes down the center of each socket, and penetrates the petroleum jelly as the socket slides onto the oil tank interface. These plastic tubes are connected to the rest of the oil puller, allowing oil and salt water to be exchanged through them.

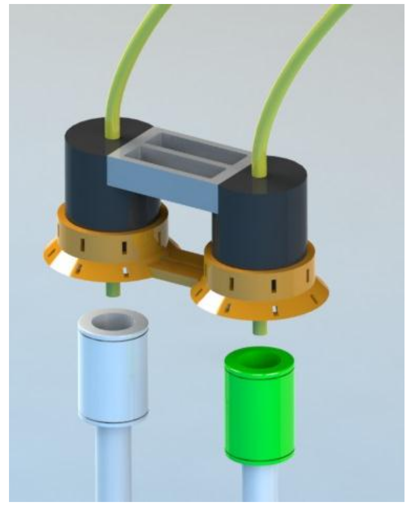


Figure 8 Tank connector

Figure 9 Oil puller

For the purpose of simplicity and size, the oil is withdrawn and replaced by salt water using a single tool. As seen in Figure 9, the oil puller consists of a large sealed cylinder with a piston driven by a variable speed power screw. The plastic hoses from the oil tank connector are fitted into each end of the cylinder, such that they are open to the interior. When the ROV is launched, the piston rests at one end of the cylinder, which is filled with salt water.

Once the oil tank connector is in place on the oil tank, a power screw drives the piston down the length of the cylinder. This forces the saltwater out through one hose, and draws oil from the tank up through the other. In this way the tool removes oil and inserts salt water not only with the same mechanism, but with the same action.

3.2.9. Patch Dispenser

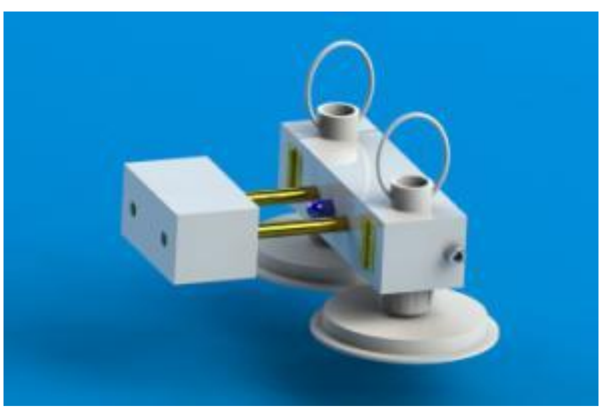


Figure 10 Patch dispenser

In keeping with the Privateers` continuing goal of speed and simplicity, both patches are placed simultaneously, and passively, with no motors or electronics.

A plastic mount was designed, which holds the patches 10.4 cm apart so they can align simultaneously with both tank ports. Each end of the mount is hinged, allowing for quick installation of the patches into the mount.

The mount rests on horizontal slider shafts, and is held to the ROV only by a weak magnet.

Once the Velcro on the caps is mated to the Velcro on the oil tank ports, the pilot simply drives away from the ship. The force of the ROV thrusters will release the magnet so the mount holding both knockout caps slides free of the ROV.

Since the knockout caps need to be placed over the oil tank interface after the oil is removed, the caps are located directly behind the Tank Connector on the ROV. This allows the Patch Dispenser to be easily positioned once the oil transfer is complete.

3.3. Propulsion

3.3.1. Design

The goal for this year's propulsion system was to keep it efficient and reliable. To accomplish this task, the team decided to use eight identical thrusters on the ROV which are easily replaceable. These thrusters were re-used from last year with some modification to improve their reliability.

Figure 11 Thruster

The custom thrusters, such as the one seen in Figure 11, were designed and constructed by the team and consist of low cost, easily replaceable components. The thruster assembly is enclosed in a watertight case made of common pipe fittings with a grease packed double shaft seal interface tested to withstand up to 207 kPa (30 psi) of pressure differential. The source of power to the thruster is a permanent magnet 24 V DC motor operating at approximately 40 W. The propellers used with the thrusters were also designed and manufactured by the team using a rapid prototype machine. The propellers are approximately 10 cm in diameter and are placed inside a cowling for increased efficiency and safety. Additionally, for safety purposes, all propellers are properly shrouded with a warning label attached.

The thrusters were effective during the 2011 competition; however, the team observed issues with cable sealing. To eliminate risk of a leak through the pipe wall, a cable was made to enter the thruster by modifying replaceable endcaps. These endcaps have a deep cavity which eliminates the risk of leakage by allowing the electrical connections to be immersed in potting. To make the endcap electrically connect to the motor, a spring loaded slip ring design was used, as shown in Figure 12.

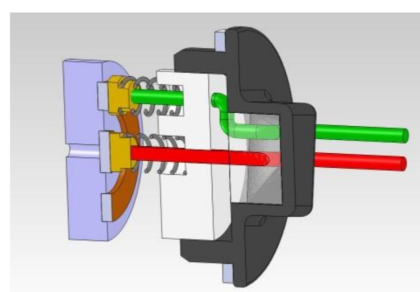


Figure 12 Endcap design

A detailed view of the thruster assembly and its components can be found in Appendix A.

3.3.2. Arrangement

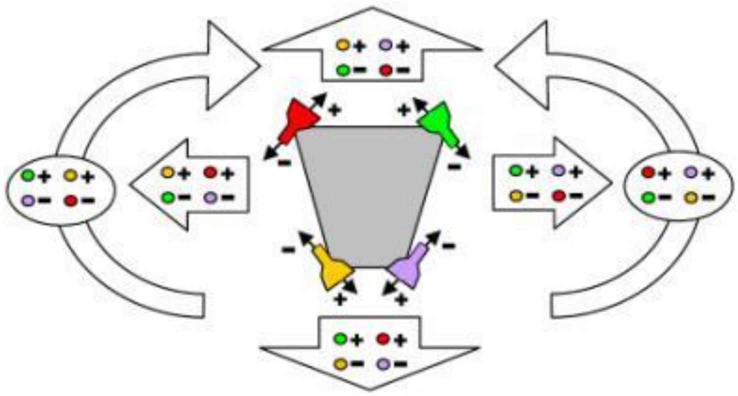


Figure 13 Thruster Configuration

To achieve horizontal propulsion the ROV uses four thrusters in vector arrangement. These bi-directional thrusters can be engaged to produce net force that not only moves the craft forward and backward but also allows it to strafe, or turn on the spot. Figure 13 depicts how this system works.

For the vertical motion, the ROV uses four additional thrusters which are placed at the four corners of the vehicle. These thrusters are split in pairs by having left and right handed propellers on them. This allows the thrusters to spin in opposite directions and not produce any net torque on the craft. The effects of thrust bias caused by uneven water column in front and behind the thruster have also been eliminated by having two thrusters pointing up and two pointing down. This allows the ROV to move up and down with the same maximum speed.

3.4. Command Center and Dry-side Electronics

3.4.1. Command Center

The Command Center (Figure 14) acts as the interface for the ROV, sending power and data to the system. It consists of a sturdy clamshell casing holding two monitors for displaying camera feeds, current control measures, power control units, and safety control measures.

Figure 14 Command Center

The command center has three monitors that are switched between the different cameras for driver operations. The video signals from the five cameras on the craft are all run through two twisted pairs of wires contained within the tether. Since there are more than two cameras on the ROV, the desired video signals can be switched by sending a command to the microprocessor on board the ROV. One main drive camera will always be displayed on the main screen, while the other views may be cycled through on the other monitors. The secondary cameras are positioned in such a way to be useful for operating tools on the ROV as well as driving.

As Figure 15 shows, the 48 V DC power supply goes through a 40 A fuse (as per MATE competition specifications) and a rectifier to avoid accidentally reversing the polarity. A switch controls the 48 V line going through the tether to the ROV. The 48 V line is stepped down to 12 V using a power converter block to power the monitors and control system.

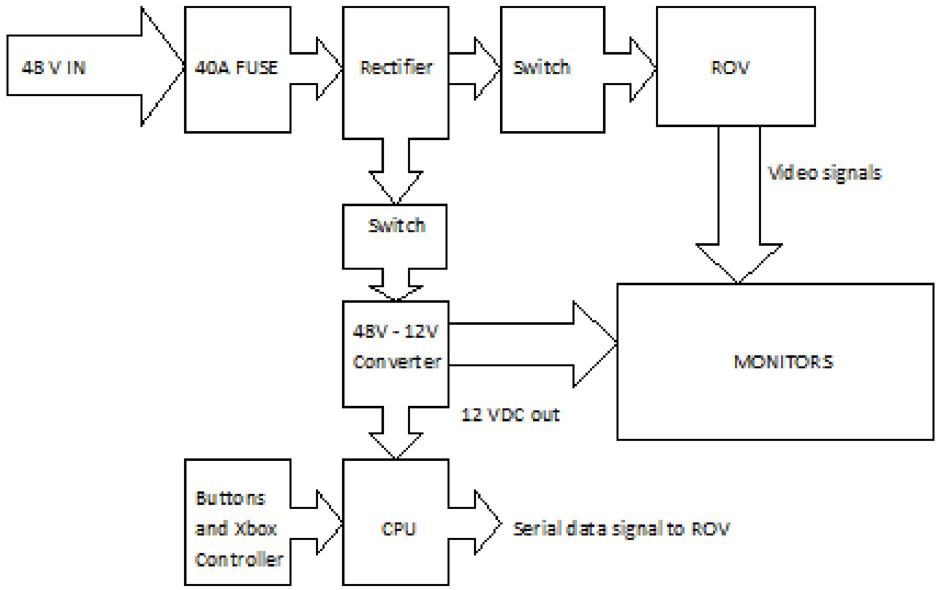


Figure 15 Command Center and Control System Block Diagram

3.5. Tether

The ROV's tether is used to transmit power and data between the ROV and the surface. The tether, supplied by VideoRay LLC, consists of ten conductors: four 20-gauge wires (power), and three 28-gauge twisted pairs (command signal, video 1, and video 2). Aside from video, no data is transmitted from the ROV. The 12 mm diameter tether measures 24 m in length, which allows the ROV to reach the bottom of the pool with plenty of slack for maneuvering. It is also neutrally buoyant with a Kevlar strength member to avoid placing an unbalanced force on the craft.

3.6. Wet-side Electronics

The ROV itself contains a tightly connected system of electronics that allow for dexterity and manoeuvrability. The customer-required 48 V supply through the tether is reduced to 12 V onboard the ROV with a buck-type switching regulator chosen for its high efficiency. This allows for a very low amount of power dissipation when running heavy loads. This new 12 V line is used to drive motors and tools, as they are not capable of handling 48 V directly. A set of linear regulators further reduces the voltage to 5 V for the transistor-transistor logic (TTL) signal. This signal feeds microcontroller, logic, and video signal multiplexers.

A PIC18F4685 acts as the microcontroller unit. This device runs at 40 MHz, with an effective speed of 10 million instructions per second (MIPS). Serial data received through the tether first passes through a SN75C1167N differential line driver, which converts from a differential to a TTL signal, and is then read by the microcontroller. A simple state machine uses interrupts that the received data generates to handle packet reconstruction.

Once a full packet is captured, the controller uses its information to update motor controller speeds, tool controllers, and switches the multiplexers if required.

Originally, in-house designed H-Bridge modules were designed and constructed to handle motor control for the craft's thrusters, but due to unresolved issues while testing, it was decided to use off-shelf modules. The controllers that were chosen are Goat 3S's from Novak. They are designed for RC use, but they were adapted to emulate the signal required to drive the Goats with the team's microcontroller. Testing demonstrated that these modules met the required specifications, and as such, the ROV is outfitted with five of them.

Tool control is handled by simple MOSFET-based switching circuits. These are able to control motors in one direction, actuate relays, and other devices. They were designed to be simple and small, requiring only an "ON" or "OFF" logic signal from the microcontroller to operate. One such module controls a relay that powers a large power LED used for the high intensity light while "scanning". This LED is a BridgeLux BXRA-56C9000-J-00, having a power handling capability of up to 5 A at a minimum of 30.4 V. The maximum luminous output from this device is just over 12,000 lumens. Testing showed this is sufficient lighting for the missions.

As mentioned earlier, due to the limited number of conductors in the tether, there was only space for two video signals back to the surface. It was determined that limiting to two cameras may be difficult, so a set of two HEF4051BP multiplexers handle switching between up to eight camera sources. The switching control is handled by the microcontroller, requiring only six I/O lines. I/O is a generous resource on our 40-pin microcontroller, and as a result, the decision to use a multiplexer was implemented.

For more information on the electronic system see the software flow chart in Appendix B and hardware schematics in Appendix C.

3.6.1. Cameras

The craft has five cameras mounted at various spots. Three of these are Delta Vision SplashCams® (pictures in , and the other two are Panvigor® underwater cameras, which have been used in previous vehicles. As stated in earlier, only two video signals are sent up the tether, so a multiplexer was used to switch between video feeds.

Figure 16 Delta Vision Camera

3.6.2. Electronics Housing

All onboard electrical circuits are housed in a custom built electronics box. This box has been re-cycled from the 2009 competition vehicle. It has been extensively modified with an improved custom connector interface.

The box was welded from 6 mm aluminum plate with dimensions of 180 mm by 400 mm by 90 mm. The box has a 9.5 mm thick clear plastic cover held down by 22 bolts against a 25 mm wide flange gasket. The inside of the box has a 3 mm aluminum plate on which the electronics are mounted. This plate was designed to be removed for easy access to repair electronics.

Figure 17 Electrical connectors

The box has one main tether connector port, three camera ports and 15 modular power connector ports, which are used for powering thrusters, tools, and additional cameras. The reason for designing these custom ports was to eliminate wire splicing outside the electronics box and to allow for modularity. The team decided that off the shelf waterproof connectors were bulky and expensive, and therefore these were not a feasible option for use with this electronics box.

To develop a compact, inexpensive, and reliable multi-connector interface, the team utilized 6.35 mm TRS connectors that are commonly used on audio equipment. This type of connector was tested to safely handle over 15 A of current (three times the expected peak) and its push-pull design made it perfect for use with a radial O-ring seal. To create a reliable seal, the team designed and manufactured a custom epoxy-filled plastic jacket to house two O-rings around the connector as shown in Figure 17. To make a small array of 15 connectors, the team machined a common receptacle from a single bar of plastic. This receptacle has series of TRS sockets mounted within it, and is bolted down and sealed to the side of the electronics box as shown in Figure 18.

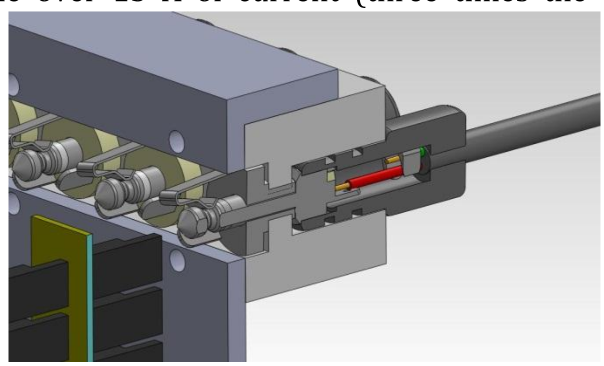


Figure 18 Electrical connector receptacle

The reliability of the custom connector interface has been successfully tested by subjecting the O-ring seals to 830 kPa (120 psi) of pressure, approximately 16 times the differential that will be seen at the bottom of the 5.2 m competition pool.

3.7. Control System

3.7.1. Overview

The control system also drives the various mechanical apparatus such as the motors and tools. The control system is adapted to include variable speed for better control of the craft. This variable speed propulsion system is controlled by Pulse Width Modulation (PWM) signals generated by the wet-side microcontroller. Motors and tools which do not require variable speed are also switched on and off by the wet-side microcontroller.

3.7.2. Data Processing

The control data is sent through the tether from the topside processor in the form of serial data packets made up of a certain number of 8 bit characters.

This chip acquires variable speed motor control data by reading the analog values from the six potentiometers in a modified Xbox controller through the 10 bit analog to the digital converter module in the PIC18F4685. The raw ADC values are calibrated in the software to provide an 8 bit number in the range of -100 to 100. Each potentiometer is slightly different so they all have their own calibration values. When the joystick potentiometers are in their zero position, they may move approximately 5% of their total rotation angle in any direction while maintaining an output of zero. This is to prevent accidental engagement of the perpendicular axis when moving a joystick in one direction. Both trigger and joystick potentiometers have a similar range at their extreme positions where the output is always 0 or 100, and +100 or -100 respectively.

The on-off data is read from up to 10 buttons connected to the I/O ports of the microcontroller. The combination of buttons that are pressed at any given time is converted to two 8 bit characters which are sent through the serial port as part of the control data packet.

For more information on the control system and data processing, see the software flow charts in Appendix B.

3.8. Frame and Assembly

As in past years, the frame was designed after the other main systems, in order to make the vehicle shape fit the required tools and tasks as efficiently as possible. The main vehicle systems were all modeled in SolidWorks® and arranged in a satisfactory layout, and then a frame layout was devised to support them. This year, however, the Privateers also had a second consideration.

In the past, it has been very difficult to service components mounted deep inside the ROV frame. Rather than constructing a full skeleton frame around the vehicle, the electronics box was used as a central core. Several aluminum members welded to the box provided mounting points for all the ROV components, without requiring a full exterior frame. Toward the same goal of easy maintenance and modification, square t-slotted aluminum pieces were used as frame members, as opposed to aluminum angle used previously. The t-slotted pieces allow components to be quickly mounted to or removed from the frame members, on any side, at any location.

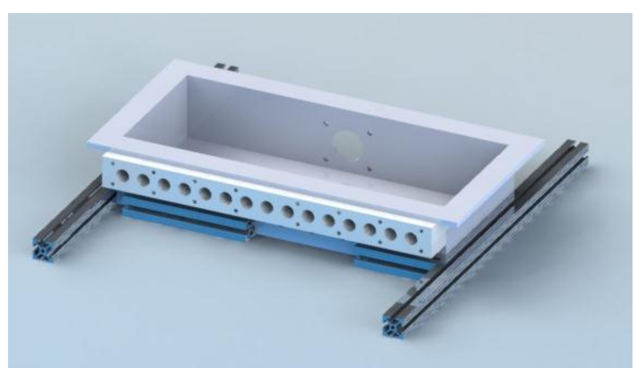


Figure 19 Frame Assembly

4. Recommendations

4.1. Challenges Faced

The major non-technical challenge we faced this year was the loss of a large portion of our experienced team. Many of our members from last year`s team graduated or decided to focus on their studies. This left us with a much smaller team. In response to this we decided to increase our recruiting focus; however, this did not lead to the needed increase in talent. With the reduction in members, a greater work load was distributed among the members and as such it was challenging to meet our usual product quality.

A major technical challenge the team faced was using our own custom built motor drivers to control the ROV's thrusters. The challenge arose during testing when several modules failed. Occasionally, and seemingly randomly, one or several MOSFETs used in the power stage of the H-bridge would fail closed, causing an internal short circuit, and rendering the driver useless. Replacing the MOSFETs only prolonged the time until another failure occurred. Troubleshooting proved difficult, but we concluded that these events were due to static discharge by users into the MOSFETs when handling the device or connecting a load, as the output terminals were connected directly to the respective drains and sources of the MOSFETs. Although every MOSFET in the H-bridge had its own separate protection diode, this did not appear to be enough to protect against the parasitic static charge damaging the driver. However, although the team diagnosed the problem, we were not able to come up with a solution. Unfortunately, with time until the competition running out, the decision was made to purchase Goat 3S modules, which are premade motor drivers made by Novak Electronics. A few members of the team had experience with these drivers in another robotics competition, and were confident that they would perform well.

4.2. Troubleshooting

The electrical connector jackets, discussed in Section 3.6.2, were initially quite difficult to insert/remove. This was in spite of the fact that the team used the correct depth O-ring grooves and O-ring for the hole. To troubleshoot the problem, we cut slightly deeper O-ring grooves in the jacket, then machined a grip surface, and then lubricated the hole with petroleum jelly. The combination of these three solutions solved the problem effectively.

4.3. Future Improvements

Every year, the Privateers strive to increase the efficiency and maneuverability of their propulsion systems. One of the goals for next year’s propulsion system is to give the pilot control over the ROV’s pitch and roll to allow our pilot to maneuver the ROV in any conceivable orientation. This would be implemented by installing three more motor drivers so the four vertical thrusters could operate independently. The software would also be modified by making the vertical propulsion program similar to the horizontal one.

4.4. Lessons Learned and Skills Gained

The largest flaw in our practice this year was that we put more of a focus into training potential employees only to lose them as they left the team to focus on their studies. This has led us to revising our recruitment practices to enforce what we are looking for and being more selective with new recruits for training purposes. This does not mean there will be any discrimination or refusal of acceptance of new team members, merely we will only be actively recruiting new members that have prior interest, such as experience in previous robotics competitions or with applicable hobbies.

A major technical skill three of our members gained this year was the ability to use a tooling lathe. We were given an introductory course at a local community college. After completion of the course, we were able to practice under the supervision of Dalhousie University technicians at the Dalhousie machine shop. This skill was extremely valuable in manufacturing the housings for our electrical connections, as well as for making motor shafts.

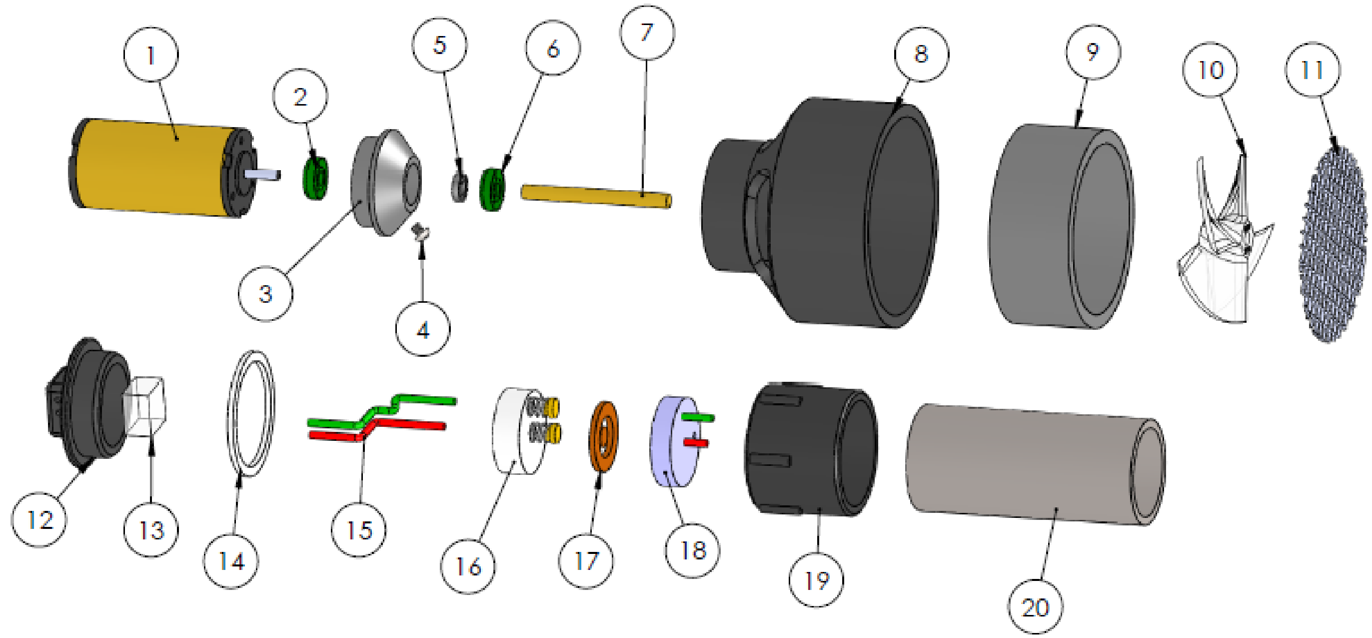
4.5. Reflections

"*Working with Dalhousie Privateers has allowed me to see the full development process of a product from ideas, prototypes, development, testing and release."* –Kathleen Svendsen, 4th year Electrical Engineering

"The ROV team has kept me grounded. It is the source of my passion for electronics classes." – Irenee Jantz-Lee, 4th year Electrical Engineering

"In the 2 years I've been a member of the Dal ROV team, I've learned more about engineering and design than the rest of my university career combined!" – Steve Doll, 5th year Mechanical Engineering

Appendix A Thruster Assemblies

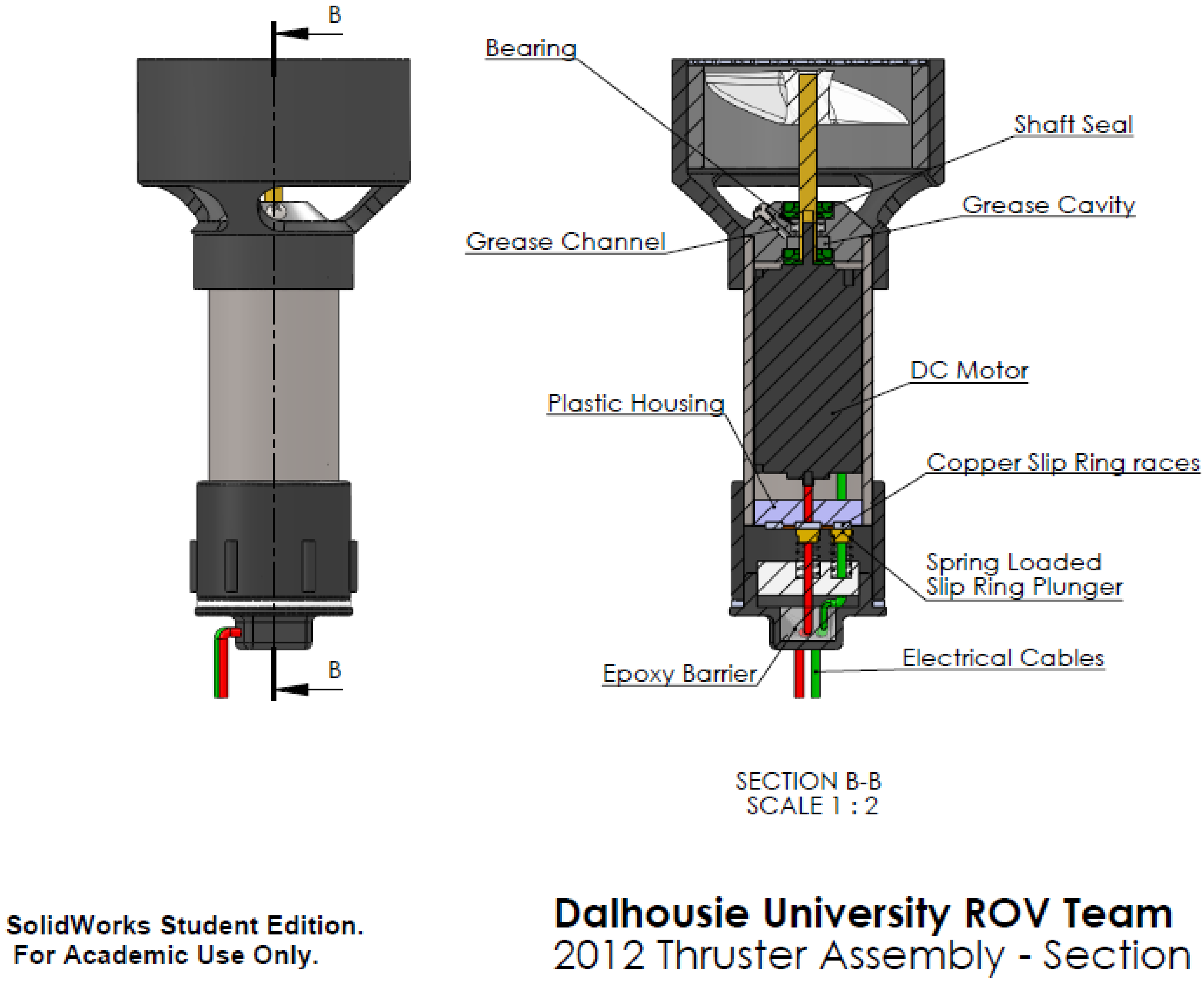


Dalhousie University ROV Team

2012 Thruster Assembly Exploded View

SolidWorks Student Edition. For Academic Use Only.

1	Permanent Magnet DC Motor	11	Steel Mesh Guard
2	Inner Shft Seal	12	End Cap
3	PVC Seal Housing	13	Epoxy Barier
4	Grease Cap Screw	14	Endcap Gasket
5	Bearing	15	Wires
6	Outer Seal	16	Slip Ring Plunger Assembly
7	Propeller Shaft	17	Slip Ring Races
8	ABS Cowling	18	Slip Ring Race Holder
9	Propeller Sleeve	19	ABS Threaded Fitting
10	Propeller	20	PVC Tube



Dalhousie University ROV Team
2012 Thruster Assembly - Section View

Appendix B Control Data Acquisition

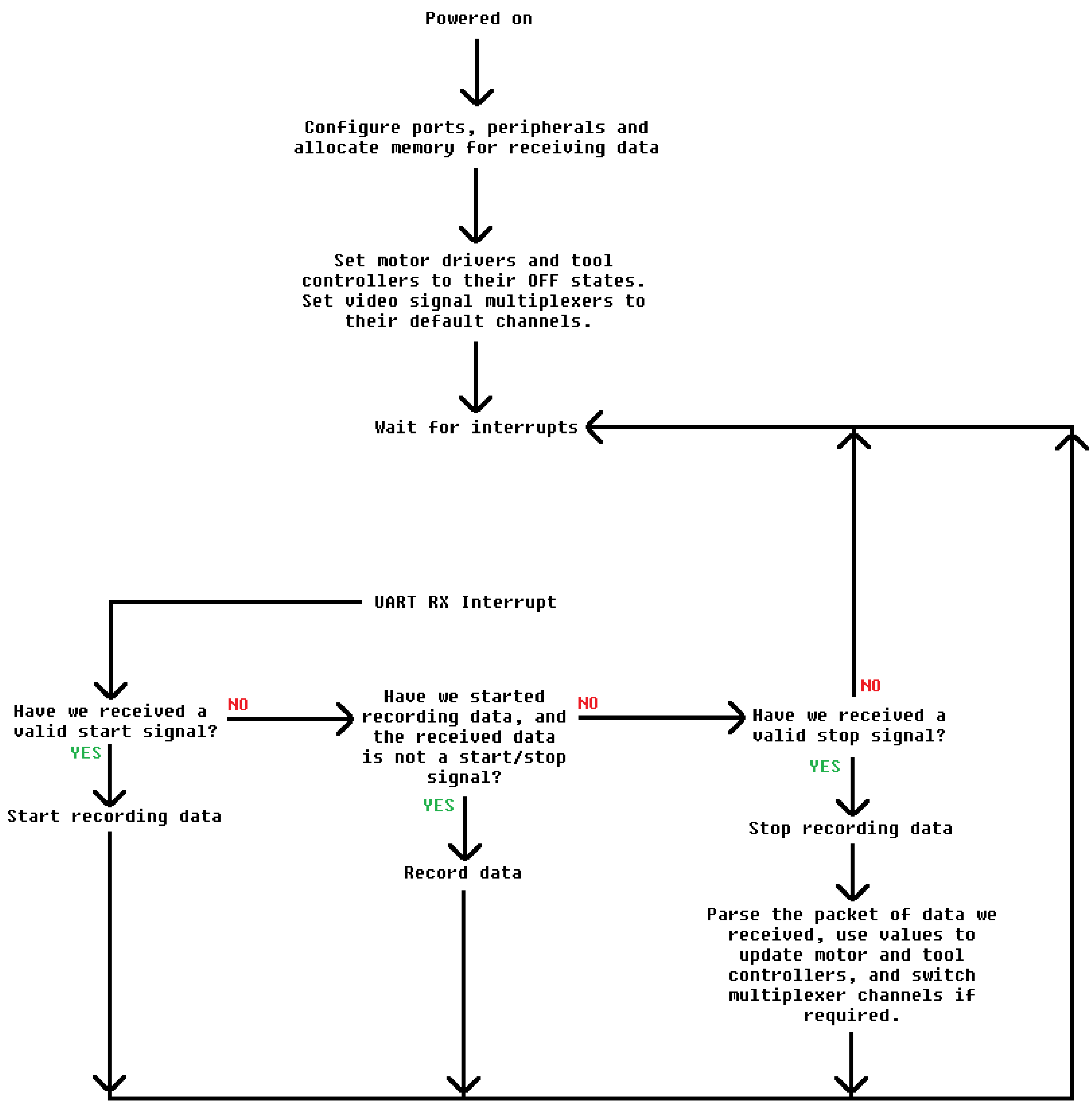


Figure 20 Wetside Software Control

Appendix C Electrical Schematics

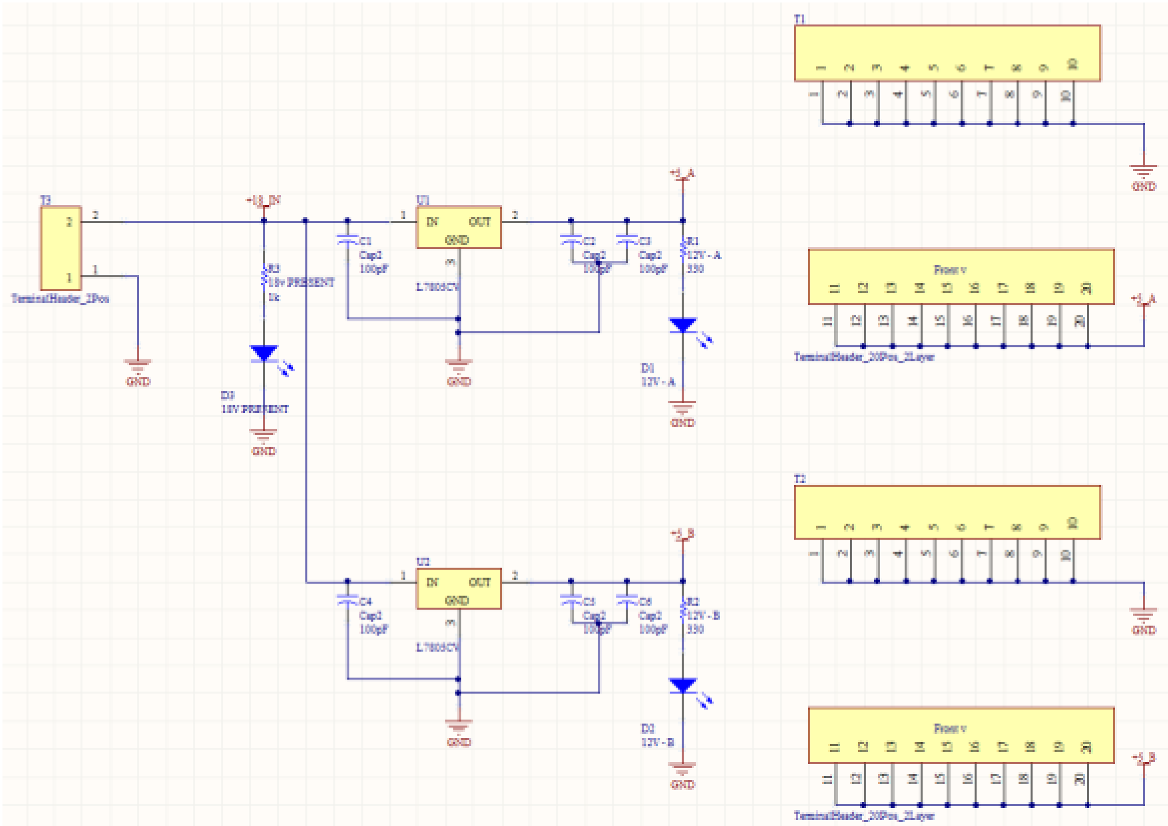


Figure 21 **Power Board**

Converts 12 V to a 5 V source for the microcontroller, multiplexer, and other logic controls

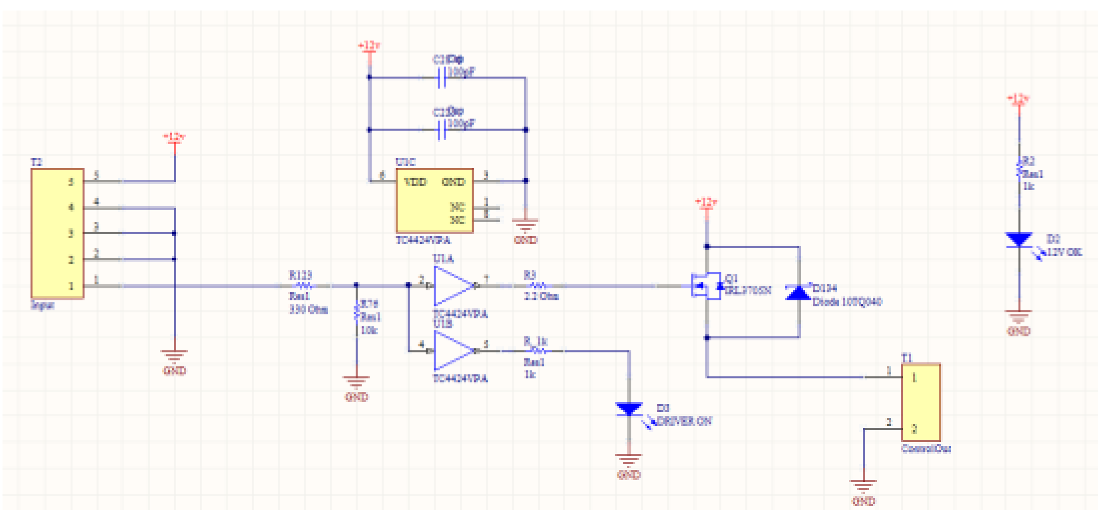


Figure 22 **Simple Driver Board**

Provides “ON/OFF” control for tool control

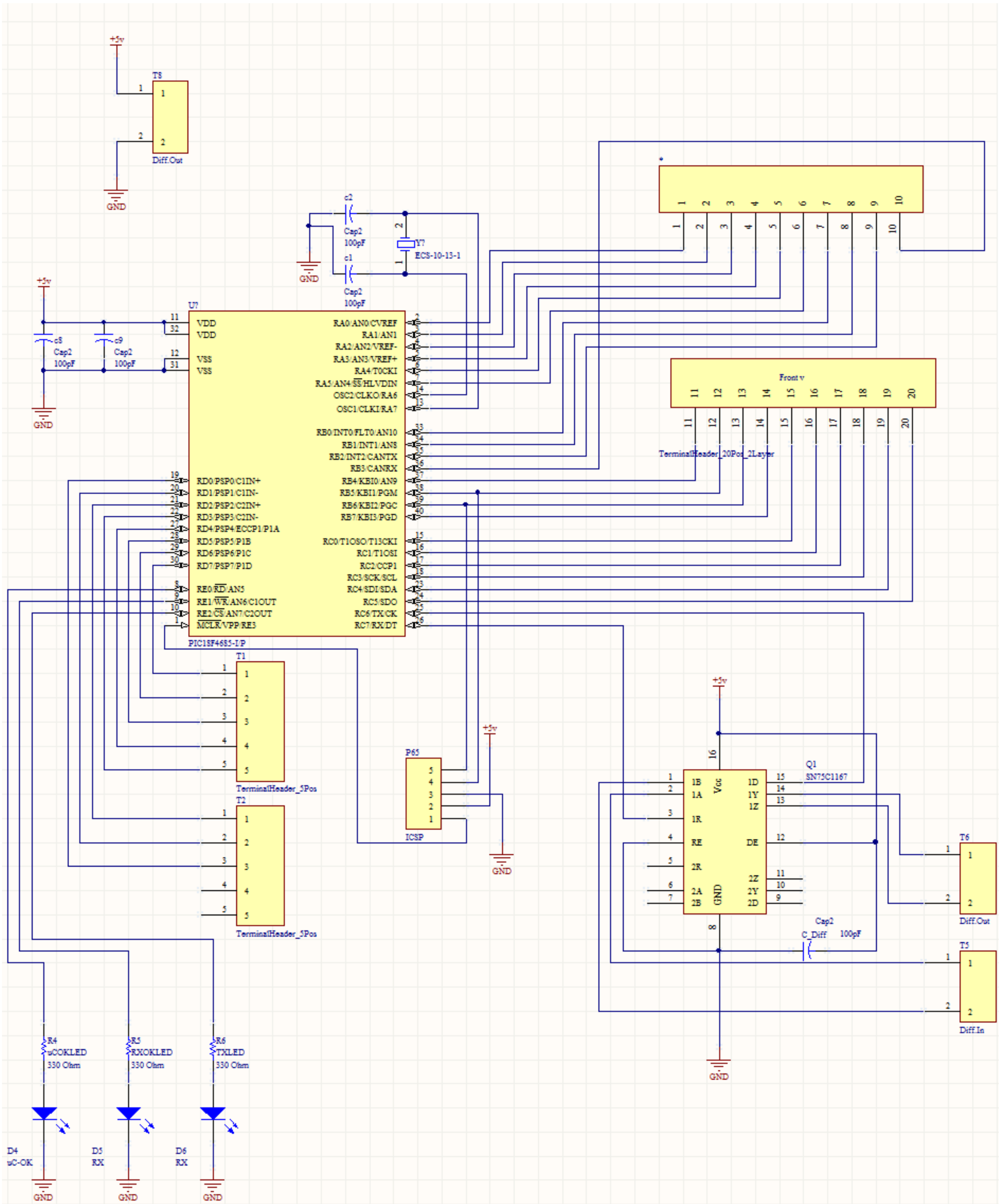


Figure 23 CPU Board

Hosts the main microcontroller and the differential driver for transmitting/receiving data.