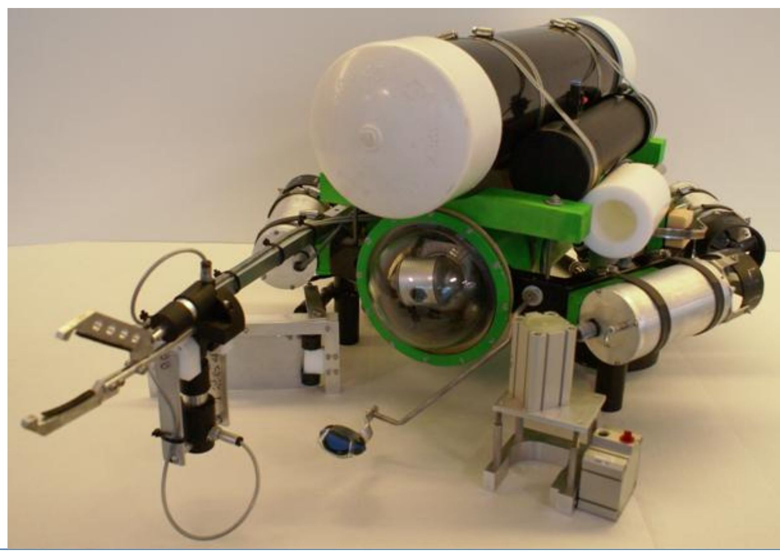
NOVA SCOTIA COMMUNITY COLLEGE

NOVA SCOTIA, CANADA

SUBMERGED TECHNOLOGIES INCORPORATED



ROV Technical Report

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Abstract

Submerged Technologies Incorporated in comprised of engineering technologies students from the Nova Scotia Community College located in Nova Scotia, Canada. This is the second year our team has participated in the MATE international ROV competition. We have learned a lot over the past two years and are excited to demonstrate all of our knowledge and hard work. Last year we managed to place 12th in the Hawaii competition and we know our craft is much more capable this year. We have built a very robust vehicle with all of the necessary tools to accomplish all of the tasks set before us. We are eager to perform our duties and are confident in our ability to succeed.

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Budget/Expense Sheet

Phase	Component	Cost$
ROV Construction	Frame	50.00
	Dome	100.00
	Buoyancy	200.00
	Tools	510.00
	Motors	1100.00
	Propellers	120.00
	Tether	200.00
	Connectors	200.00
	Electronics	745.00
	Camera	500.00
Competition Expenses	Air Fare	3000.00
	Food and Accommodations	1500.00
	Shipping	700.00
	Total Cost	8925.00

Design Rationale

Electronics

Program/Controller

This year we wanted to have a craft that was as user friendly as possible. Last year's craft used switches to operate the motors. This design was easy to implement but made it difficult for the pilot to operate the craft. Due to this we researched and discussed ways to make the controls as simple as possible. After extensive research we discovered the ease with which an XBOX 360 controller could be used in conjunction with LabView, a graphics based computer programming software.

With LabView we were able to plug a wired Xbox 360 controller directly into the USB port of a computer and read the inputs given. We designed a Labview program (Appendix A) to convert the inputs given from the controller to data that could be easily understood by a micro controller. Once this was achieved the data was outputted through another USB port. This USB port was connected to our control box using a UB232. From the control box the data then gets transmitted through the tether using TTL communication to our onboard microchip (PIC16F887). To be able to use all the buttons and multiple directional movements of the XBOX 360 controller, we constructed two, eight bit strings in Labview where each bit represented a different controller input. The PIC16F887 (Figure 1) is an 8 bit micro chip and in order to utilize all the required controls, we had to send two 8 bit strings from Labview. We next had to think of a way for the PIC to distinguish between the two strings. This was accomplished by making the most significant bit high on one of the strings and low on the other.

Figure 1: PIC16F887

Then we programmed the PIC to read these inputs and act accordingly. Since Labview had already turned the data into a binary format it was relatively simple to write a C-code that would read the 8 bit strings. Since each bit represented a different button or thumb stick movement on the controller, the C-code had to turn certain ports high and low depending on the input.

After assembling the final craft our transmission signal was being distorted by electrical noise. This caused motors and tooling to turn on randomly when other commands were given. To solve this we had to modify our C-code so that it had to read the same input three times before it would turn anything on.

Circuit Boards

Last year's team consisted of solely first year technologists. This limited our knowledge to basic electronic and electrical systems. This year's team now has second year technologists and has helped the designing of the controls immensely. We were able to design our own circuits as well as mill our own circuit boards (Figure 2). This was a huge benefit because the team had all the resources to complete a circuit from start to finish. We experimented with the milling machine and made multiple testing boards. At the end of testing we produced three circuit boards; one for our main circuit board (Appendix B); one circuit board for the relays and pneumatic activation (Appendix C), and another for our UB232 at the surface. We used these boards for testing our craft as well as the regional competition. We are outsourcing the main circuit board fabrication before the competition, to a recognized circuit board manufacturer, to increase reliability.

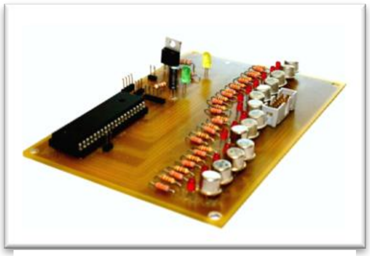


Figure 2: Circuit Board

Cameras

This year we wanted to have one main camera with the ability to pan and tilt instead of multiple cameras. After researching various types of cameras, we decided to use an Ethernet camera (Figure 3). There are various types of Ethernet cameras on the market so it took a lot of research

Figure 3: Ethernet Camera

to find a suitable one.

The camera is placed on the front of the craft for navigating, as well as tool observation. It is controlled by a laptop computer at the surface. A disadvantage of an Ethernet camera is the price. In order to receive the same amount of frames per second that a USB camera offers we had to increase our budget for cameras.

Power Distribution

According to the Design and Building Specifications of the competition we are given a 48 volt source. Since it is required to send all the voltage to the craft our design required us to have multiple voltage regulators. We used two 12 volt regulators and one 24 volt regulator which allowed us to distribute various levels of power to all electronic devices. The 24 volt regulator was used to power four of our six motors. This design allows the motors to draw up to six amps each. One of the 12 volt regulators is used to power the camera and the main electronics board. It is capable of powering more electronics, but to reduce electrical noise we decided to use a separate 12 volt regulator for the remaining two motors. We decided to use a 12 volt regulator for the remaining two motors because our vertical propellers were designed to operate at a lower rpm. The specifications of the DC to DC converters state that they will be operational when they receive a voltage supply over 36 volts. This will allow adequate room for voltage loss caused by the tether.

Tether

This year the team invested in an industry grade tether. It consisted of four power wires and six data communications lines. A lesson we learned from last year's craft is to have a neutrally buoyant tether that was light weight. This will allow the craft to maintain maneuverability at long distances. Another major improvement from last year's craft is the reduction in voltage losses due to the wire quality. The tether was a very good investment for our team and future NSCC ROV Teams.

Propulsion

Motors and Relays

To limit the time spent on motor housing design and fabrication we decided to use six identical motors for all propulsion. Four motors are used for horizontal propulsion and two for vertical propulsion.

The motors are placed in a vectored pattern (Figure 4) to allow for multi directional movement. This allows the craft to use two motors to achieve one of four methods of movement: forwards/backwards; rotation left/right; strafe left/right; up/down.

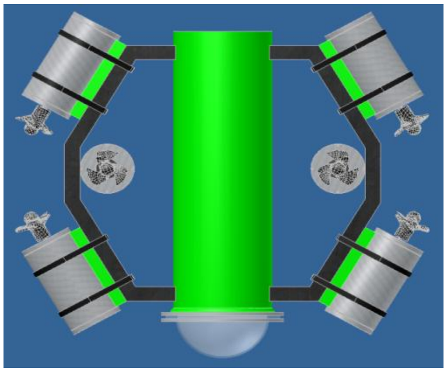


Figure 4: Vector Design

The amount of power required to sufficiently propel the craft had to be kept in consideration when researching the motors. Based on our 12 to 24 volt power supply we eventually determined that motors requiring approximately 6 amps would be adequate.

To activate our motors we used relays (Figure 5). Relays allow for a simple, reliable circuit. Besides our microchip requiring to be programmed, the relays are a turn on turn off component. The only consideration needed when selecting the relays was start up current. The general rule when using relays and DC motors is to double the current rating. This will prevent any fires or shortening the life of the component.

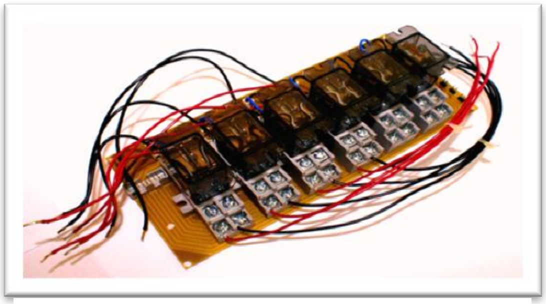


Figure 5: Relays

During our initial testing, we tried to implement a Pulse Width Modulation (PWM) Motor Control Board to control the vertical motors.   PWM would have allowed us to have variable speed up and down thrust.   This turned out to be a difficult option to incorporate with the rest of the craft. Due to the high current spikes related to the PWM our camera would shutdown as well as our DC to DC converter which supplied the PWM motor control board.

Motor housings

During the initial conception of our motor housings it was decided to use metal to attempt to facilitate heat transfer away from the motors. For this reason the motor housings (Figure 6) are constructed of aluminum due to its lower weight and high heat capacity.

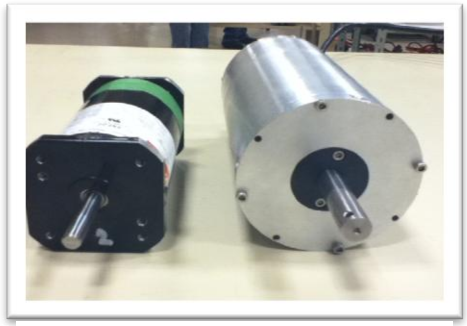


Figure 6: Motor and Housing

It was difficult to ensure that the shaft seal of the motor housing was water tight. We initially selected O-rings to seal the motor shafts. During testing we occasionally encountered leaks which we believed were a result of a poor shaft seal. We attempted different seal configurations and eventually x-rings were selected because they fit in the existing O-ring glands. The new seals provided lasting results even when encountered with non-concentric shaft operation. We speculate this is due to the two sealing surfaces in contact, as well as a small grease pocket that is trapped in the seal during operation providing greater friction protection.

Another design feature of the motors is a check valve installed in each of the housings. This allows for a vacuum generator to produce a negative pressure within the housing. This does two things. First, it is an indication if the motor is still sealed; and second, it pulls the seals into place much like they would if they were under pressure from depth.

Propellers

This year we decided a key point of our propulsion design would rely on choosing the right propeller for our motors. At first we began looking at different options available in our area but found it difficult to find ample selection. We later were fortunate to have access to a three dimensional printer that could print objects created with solid modeling computer aided design software (Figure 7).

Figure 7: 3D Printer Propellers

At first we were not certain if any propeller printed off would be strong enough. After further research we found that there were different treatments that could be applied to a propeller to increase its rigidity, notably covering it with epoxy.

Initially we began our propeller selection based on our motor power requirements. We understood that the horizontal motors would be supplied a theoretical constant 24 volts with approximately 6 amps of current. To attain a propeller that matched this profile we had to follow an iterative process of testing and design modifications until a final design was achieved.

We also required two motors that could run in both forwards and reverse to move up and down. For these motors we created a propeller that was more efficient in both directions by adjusting the pitch of the blades.

Testing Rig

With the 3D printing of propellers of different characteristics and sizes, testing needed to be done to determine the best propellers to use. Initially we performed tests that did not produce accurate thrust data but simply indicated a reading relative to the other propellers. The scale that was used was a spring scale which was inaccurate and the tester itself was unstable.

A new design was created which involved the use of an arm connected to a static digital scale that would not move which permitted increased accuracy when inspecting the thrust created by the motors.

Vehicle Structure

ROV Hull

The main hull is where the electronics and camera are housed. A standard 6” SCH 10 steel pipe was chosen for the hull to allow plenty of room inside for the electronics and camera. A flange was welded onto the front of the hull where an acrylic dome is fastened; the flange was cut using a CNC plasma cutter and then welded to the front of the pipe. The back of the ROV hull needed to be machined so there would be a smooth round surface for the o-ring to mate with. Steel supports were also welded to the side of the main hull to provide locations to mount motors and tooling (Figure 8). Overall in the end the relative dimensions of the craft are 120 cm long, 74 cm wide and 40 cm tall with an overall weight of nearly 45 kilograms.

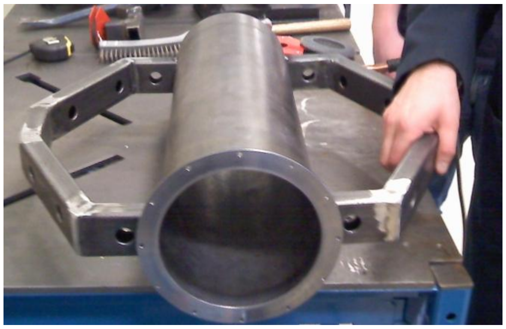


Figure 8: ROV Hull

End Cap Design

Once the hull was machined an end cap design was created to properly seal the hull. Initially we thought we would use one large O-ring but after practical calculations however, two smaller O-rings were chosen to be used. After the cap was machined it was tested, it fit and sealed properly.

Electronics Housing

The electronics needed to be securely fixed to the inside of the ROV hull and be easily removable from the ROV. The heat from DC to DC converters also needed to be dissipated. In order for all the electronics to fit inside the ROV hull, the tray had to be mounted at a specific height which was achieved by welding mounting blocks on the interior of the hull.

The system is designed so that the electronics board slides into the front blocks and rests against a rubber bumper; then, the back of the tray rests on top of back blocks where it fastens to it.

Buoyancy

One aspect the team focused on managing carefully this year was buoyancy and craft stability. The team particularly wanted to ensure that the ROV was capable of “hovering” with little or no change in depth regardless of how deep it was in the pool.

In the 2010 competition the ROV was unstable as soon as it began to descend past a meter of depth, at which point it would begin to sink. This was because the foam began to compress, reducing the amount of water it displaced.

This year the team began by choosing foam samples with higher density that was able to resist more compressive forces. Syntactic foam is a commonly used material in the ROV industry; however, the team tried to reduce costs as much as possible and therefore sought out other alternatives.

The team selected several different types of foam and tested them by placing them in a sealed container full of water which had increasing pressure applied to it using pneumatics (Figure 9). This enabled the team to simulate and observe the behavior of the foam at increased depth. After applying pressure none of the foam samples were able to remain floating after an increase in depth. At this point a decision was made to use a rigid buoyancy source such as a sealed tube or box.

Figure 9: Sealed Testing Container

Before selecting the exact structure and size of rigid buoyancy the team determined the wet weight of the ROV. This was done by suspending the entire vehicle in water from a scale. After determining the wet weight of the craft to be approximately 15 kg the team performed calculations to determine how much water needed to be displaced to achieve neutral buoyancy.

At that point the team selected an appropriate size abs pipe that was close to the length of the hull of the ROV. The team was also fortunate to receive some left over pieces of syntactic foam from a local marine company. It is not enough foam to contemplate using it as buoyancy for the entire ROV; but, it did provide a useful tool for small adjustments to buoyancy.

Task Specific Tooling

Pneumatics

One successful component of the 2010 design that was carried forward to this year is using pneumatics for all of our tooling needs. It is reliable and provides responsive tooling that is robust.

There are two pneumatic systems on the craft. The first system consists of pneumatic solenoids mounted a manifold. They are mounted inside the hull where they receive electronic signals to control them. They are responsible for delivering air pressure to different tooling on the craft. The system is designed to receive pressure from the surface, and exhaust under water without any fluid interaction within the internal hull. All pressure is exhausted to the outside water through redundant check valves. The submerged exhaust eliminates a separate line back to the surface allowing for a smaller tether.

It is apparent that if there was a leak within the hull, the pressure could be catastrophic. To combat this there is a check valve in line with the exhaust manifold. If pressure were to leak into the hull, it would open the check valve and safely vent into the water.

The second pneumatic system is containers attached to the top of the craft. It is connected with a separate line with a manual control valve located on the surface. The primary purpose of these containers is to dial in buoyancy and/or assist the vertical motors to elevate more quickly. Its secondary purpose is to recover the craft in the event of electronic failure rendering the vertical thrusters ineffective. It is capable of surfacing the craft quickly without putting any undesired stress on the tether.

Task 1: Remove the Damaged Riser Pipe

For the first mission of this competition the ROV is required to attach a retrieval line to a damaged piece of pipe. The ROV is then required to cut off the piece of damaged pipe by removing a piece of Velcro.

The team decided that it would be useful to use a single tool to achieve both of these tasks within the first mission. It seemed like a claw arm would be an ideal tool to remove the Velcro from the pipe. This claw could also be used to attach the retrieval line to the damaged pipe.

The team decided to make some adjustments to a claw arm used in the 2010 competition. In 2010 the claw was capable of turning outwards like a screw. This year the team decided that they wanted the claw to remain at a constant distance but retain the ability to rotate so that it could close its jaws vertically or horizontally. A new turning joint was machined out of a plastic called acetal. The remaining parts of the claw from 2010 were constructed primarily from aluminum (Figure 10). All of the actuators used to rotate and close the jaws of the claw used pneumatic cylinders.

To maintain simplicity a device similar to a carabineer would be used to attach the retrieval line to the damaged piece of pipe. To enable the claw to hold the carabineer foam was shaped to fit in the claw jaws and then the carabineer was fastened to the foam.

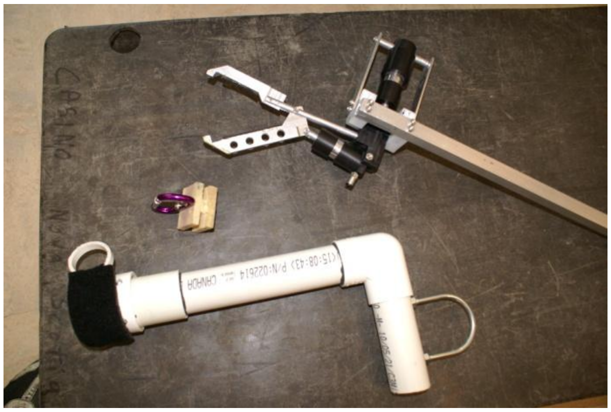


Figure 10: Claw

Task #2: Cap the Oil Well

During the initial design phases many ideas were circulated on how we could cap the flowing well. Most spring or mechanical designs provided only one attempt at capping the well. Any electrically driven designs could never be entirely reliable for they depended too much on multiple sealing points. It was decided the clamping and capping mechanism be powered by a pneumatic system due to its robust nature and simple operation. Several linkages were studied using small diameter rams in which a mechanical advantage could clamp and cap in one motion. After analyzing build complexity and forces acting on the well head, it was apparent that nothing could compare to the power and simplicity of utilizing two large diameters rams to first clamp, and then cap the well with no linkages. The final advantage to utilizing air as a power source is the ability to disconnect from the well head while enclosed pressure remains acting in the cylinders.

The pipe capping device is constructed of pneumatic single acting rams, and pneumatic solenoids, which will be active from the surface once in place over the flowing well head. A first horizontal ram will close, securing the craft and the clamp in place. Shortly after, a vertical flow controlled ram will wedge a rubber stopper into the open pipe. Small streamers will indicate any leaks to the pilots so that they can release the clamp, and readjusting their position if so desired. Once they are satisfied with the lock and no flow is present, a third pneumatic ram will be activated, which releases the pipe capping device from the craft. The pipe capper will remain fixed in position with pressure still acting on the clamp and the stopper. To recover the pipe capping device, a simple needle valve has been installed which can be turned by a diver, or the crafts rotating gripper. Once the needle valve has been cracked, pressure will drain through a check valve into the water. The single acting rams will return to their resting posting with the assistance of the built in springs. The cap will then rest free in the water ready for pick up from either the ROV, or a diver.

Task #3: Collect Water Samples and Measure Depth

The third task of the competition the ROV is required to collect a sample of water. We decide to base our design loosely on the concept of a syringe. A piston is actuated in an open ended cylinder, thus drawing in fluid which is stored in the body of the cylinder. The fluid is extracted from the container on the outward stroke and expelled from the ROV on the return stroke. The pneumatic cylinder must remain under pressure until the sample is ready to be expelled, or the spring return will cause the sample to be expelled prematurely.

Figure 11: Water Sampler

Our Water Sampler (Figure 11) is mainly constructed of acetel plastic because it is easily machined, durable and inexpensive to attain.

Clear pneumatic tubing is used to transport the fluid from the container to the syringe piston. We chose clear pneumatic tubing because it allowed clear visibility of the liquid being extracted from the container. A spring-returned, pneumatic cylinder is used to actuate the piston of our water sampler.

To collect depth measurements we are using a divers watch to display depth. This was a simple solution for our team because one of the team members dives regularly and already had this cost efficient and accurate depth measurement tool.

Task #4: Collect Biological Samples

For the biological mission stationary bio samples on the floor of the pool have to be gathered by the ROV. To accomplish this pneumatic door within a frame attached to a net was designed. This enabled the door to swing open and then swing closed into the frame, pushing the bio samples into the net. A net was chosen as opposed to a rigid box to reduce weight and potential drag as the ROV traveled through the water.

Troubleshooting Challenge & Learning Experience

The electronic members of the team made drastic changes from the control, and instrumentation of last year's craft. With the team having a brand new control system, major bugs had to be ironed out. The first major issue the electronics team faced was the noise factor do to the increase load caused by the propellers when submersed. This was a major issue due to the on board microchip requiring a clean signal to decipher the commands from the controller. We tried using an opto-complier to separate the grounds. This was not successful due to the slew rate of the chip. We then tried using capacitors to reduce the noise. The capacitors helped remove part of the noise but the technique that solved the issue was sending a ground wire from the microchip to the UB232 on the surface. The lesson we learned from this problem was to have a troubleshooting rationale. Problems can become much more severe if a plan is not set in place. By discussing the problem you can pin point the issue much more efficiently. We also learned while troubleshooting it is always good practice not over think problems, and make assumptions, since it usually ends up being the simple issues like solder joints and loose connections.

Discussion of future improvements

In the future many components of the ROV could be improved. This year's craft ended up being very heavy. One change that could be made in future would be to reduce the size of the motors and craft simultaneously to reduce overall weight.

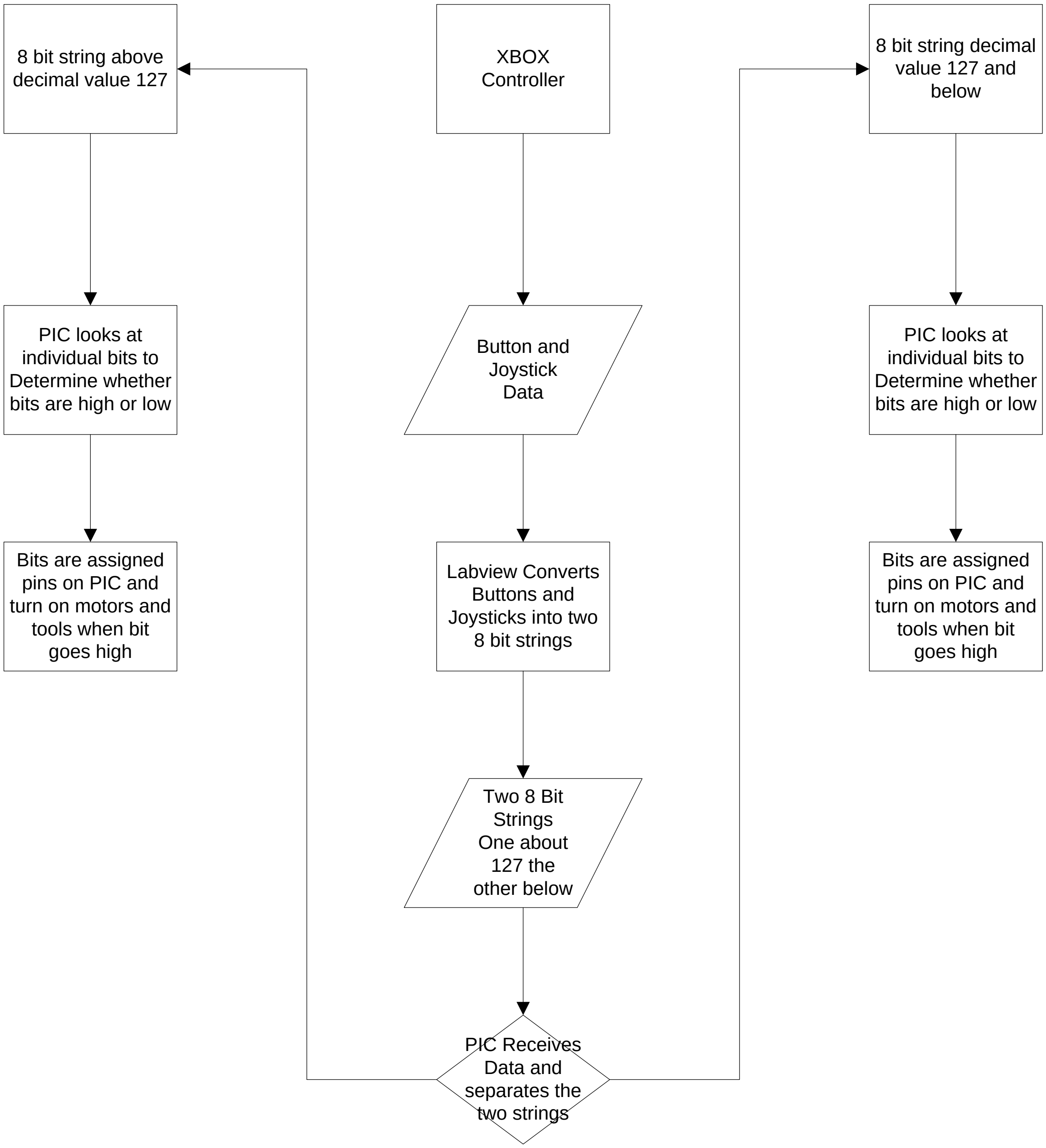
Reflections on the experience

Overall our team overcame many difficulties this year to create a very capable machine. We are all very excited to participate in the competition and continue to learn about the ROV industry as a whole.

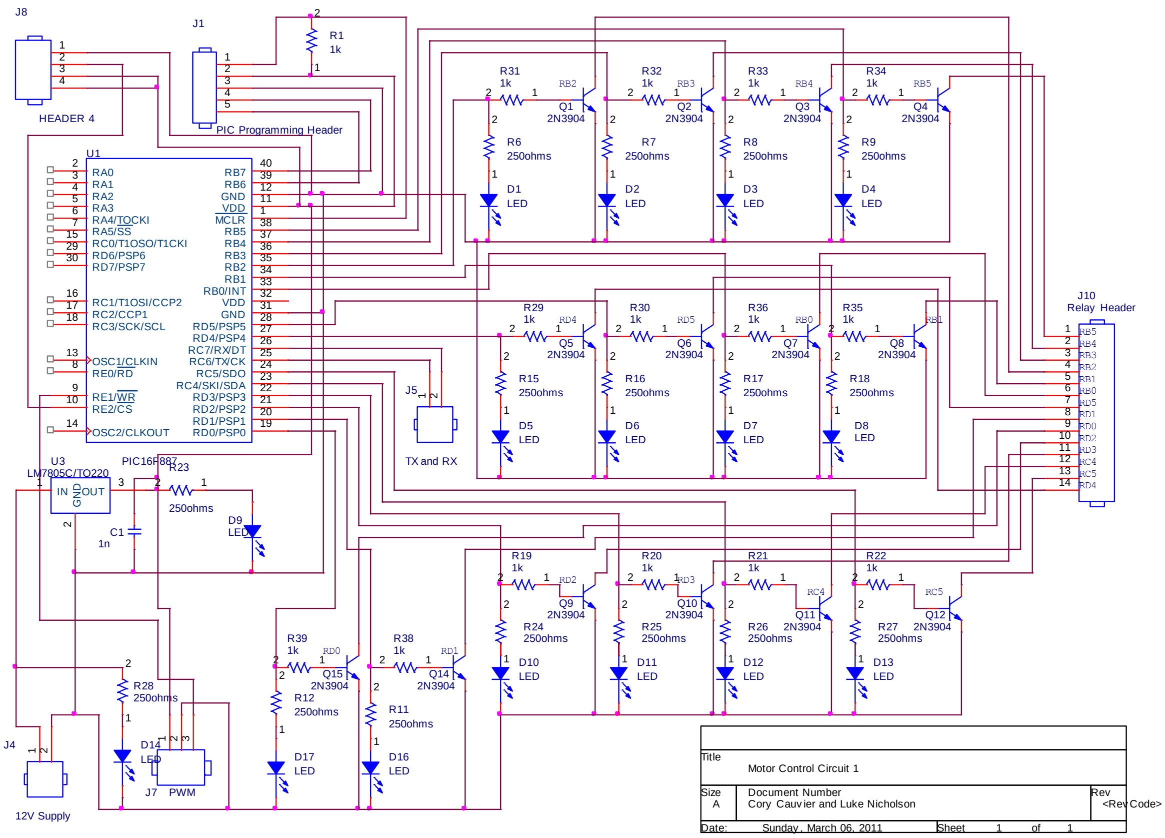
Acknowledgements

We would like to thank our mentor Peter Oster for all his help and guidance with the ROV both this year and last year. We also owe a great debt of gratitude to all of the teachers within the NSCC who provided advice or help with manufacturing over the past 8 months.

Appendix A


8 bit string above decimal value 127
XBOX Controller
8 bit string decimal value 127 and below
PIC looks at individual bits to Determine whether bits are high or low
Button and Joystick Data
PIC looks at individual bits to Determine whether bits are high or low
Bits are assigned pins on PIC and turn on motors and tools when bit goes high
Labview Converts Buttons and Joysticks into two 8 bit strings
Bits are assigned pins on PIC and turn on motors and tools when bit goes high
Two 8 Bit Strings One about 127 the other below
PIC Receives Data and separates the two strings

Appendix B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J1
PIC Programming Header
R1
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U1
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RA1
RA2
RA3
RA4/TOCKI
RA5/SS
RC0/T1OSO/T1CKI
RD6/PSP6
RD7/PSP7
RC1/T1OSI/CCP2
RC2/CCP1
RC3/SCK/SCL
OSC1/CLKIN
RE0/RD
RE1/WR
RE2/CS
OSC2/CLKOUT
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RB6
GND
VDD
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RB5
RB4
RB3
RB2
RB1
RB0/INT
VDD
GND
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RC6/TX/CK
RC5/SDO
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R32
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Q2
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R30
R36
R35
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Q6
Q7
Q8
R15
R16
R17
R18
D5
D6
D7
D8
J10
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R22
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Q11
Q12
R24
R25
R26
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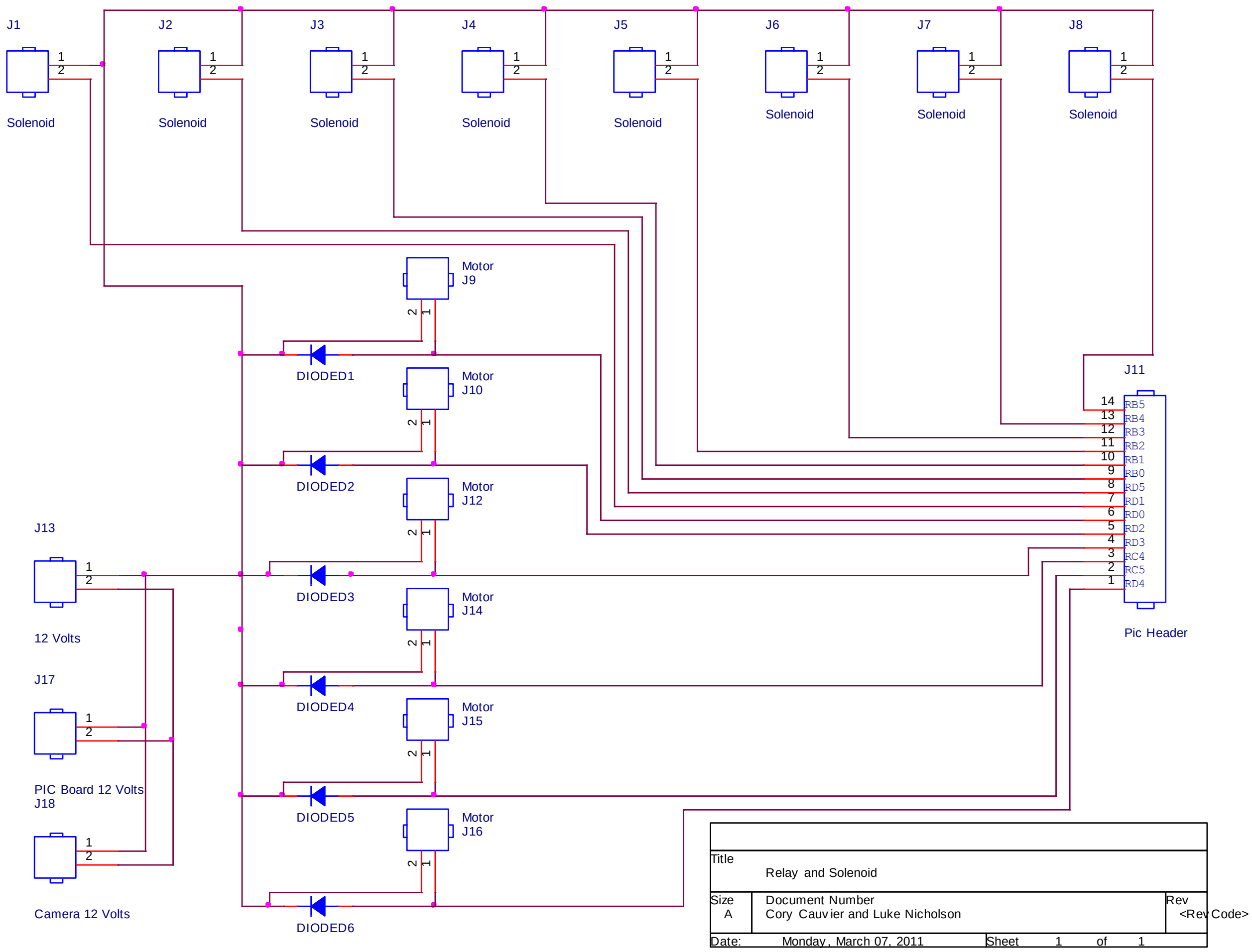
Appendix C



J1
J2
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Motor J9
Motor J10
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Motor J16
DIODED1
DIODED2
DIODED3
DIODED4
DIODED5
DIODED6
J13
12 Volts
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Camera 12 Volts
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RB0
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