The MIT ROV Team Presents:
WiiBot I

Massachusetts Institute of Technology

Team Members

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Abstract

This year, the MIT ROV Team developed their fifth ROV for the 2007 MATE ROV competition, the WiiBot. The WiiBot is first focused around completing the tasks presented the competition. There are three mission packages to accomplish the missions for the competition. The first package will thread a fiber through a U-bolt by using a mechanism held on by magnets. The second package is able to release and capture the many objects of the second mission from its 15.4 cm tube. Finally, the third package is able to install a gasket and insert a hot stab into the third missions' setup. The WiiBot is built on a stable platform with four thrusters, a microchip based underwater system, a computer based topside system, and a work in progress navigation system, all held together with 10 batteries, a sturdy frame, and a fiber optic tether.

The 2007 robot proved to provide many invaluable experiences for the team. The opportunities have ranged from working with children and teaching the values of running an ROV to getting dirty in a machine shop and always remembering to measure twice. While some of the systems were used from the year before, many new systems were implemented, providing the real world experience not obtainable in the classroom. This year's robot has tried to push the limits of not only the technology, but of the students developing it.

Design Rationale

This year, the MIT ROV Team focused on two objectives. First, the requirements of the 2007 MATE ROV Competition needed to be met. The first three sections are devoted to the first, second, and third mission modules developed to complete the competition tasks. The other objective of the team was to develop a robot with new technologies and push the limit of how small, robust, and powerful a ROV of the class could be. The sections devoted to frame design, the control systems, and the navigation system are directed not only at completing the competition, but meeting this secondary objective.

Mission 1

For the Mission One component of the 2007 MATE ROV competition, a simple yet elegant and effective device was devised to accomplish the task of threading a rope through an eyelet in the presence of an underwater current.

The device, as shown in Figure 1, consists of two machined pieces of acrylic, which are placed one on top of the other. There are two sets of magnets, one at the front of the device and one at the back. The u-bolt, which the cord must be passed through, splits apart the first set of magnets while the back set remain in contact. The positive buoyancy of the device provides a restoring force, which reinstates contact between the front set of magnets. This process is again repeated with the rear group of magnets. The cord is attached to the bottom section of the device, which is passed fully through the u-bolt, and thus the cord is also successfully threaded through the u-bolt. The whole device is attached to the bottom of the ROV.

In order to optimize the performance of the device, a flexure was placed in between the sets of magnets. This allows better contact to be maintained between the set of magnets, which is not separated while the u-bolt separates the other set. The flexure was modeled as a simple beam-bending problem with one end constrained and the other end free to be deflected by some load, which in this case is the separating force of the u-bolt. The lengths (l) of the flexure, its width

(b), the load (P), the amount of deflection (d), and the material used (Young's Modulus E) have been constrained by the design. Hence the only variable value is the height of the flexure, given by equation 1.

$$h = \left(\frac{6 \cdot Pl^2}{Eb \cdot \arctan(d/l)} \right)^{1/3} \tag{1}$$

Using an approximate load of 10 N, 0.0762 m as the desired length, 3×10^9 Pa as the Young's modulus for acrylic[1], 0.025 m as the width of the flexure, and 0.019 m as the desired deflection, the height of the flexure is found to be 0.00265 m.

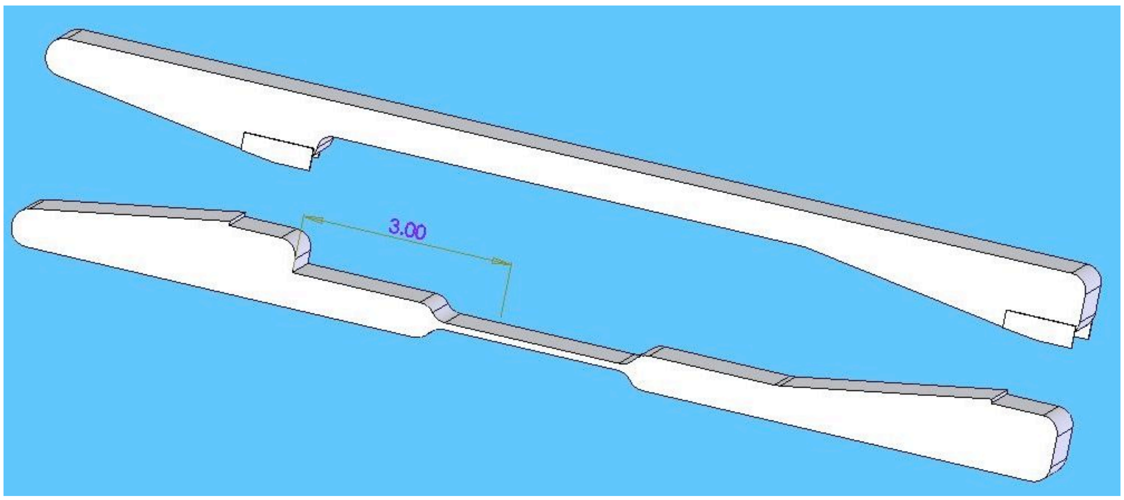

Figure 1 - Mission 1 apparatus separated apart

It was also necessary to determine the amounts of flotation foam and acrylic which must be used in the device to provide positive buoyancy. The amounts required were found by simultaneously solving equation 2, where V_a is the volume of the acrylic, V_f is the volume of the flotation foam, ρ_a is the density of acrylic, and ρ_f is the density of flotation foam, and equation 3, where V_T is the total volume of the bottom portion of the device, or the portion which must be positively buoyant. These two equations represent the conservation of mass and volume. Using for the density of water 1 g/cc, for the density of acrylic 1.18 g/cc [4], for the density of flotation foam 0.60 g/cc, and for the total volume of the bottom portion of the device 1.14×10^{-4} m^3, it was found that the volume of the acrylic should be 4.86×10^{-5} m^3 and the volume of the floatation foam should be 9.24×10^{-5} m^3.

$$\rho_w (V_a + V_f) = 1.5 \cdot (\rho_a V_a + \rho_f V_f) \tag{2}$$

$$V_a + V_f = V_T \tag{3}$$

[1] MatWeb, Material Property Data, 2007, available from Internet; accessed 17 May 2007.

Finally, to insure the proper alignment of the two sections of the device with respect to each other after the separation of the magnets, notches were added to the device on the sides of the magnet contact points.

Mission 2

The second mission for the 2007 MATE ROV competition was to capture an O-ball on the ground, a ping pong ball floating against a sheet of ice, and deposit an acoustic sensor onto the ground. The following system was built to accomplish this task

The main structure of the module is a 15.25 cm diameter 25.4 cm length of plastic tubing. Attached to either end of the tube is a circular cap made of 1.6 mm thick sheet aluminum. The caps have square protrusions, which allow for attachment of the caps to servo motors, which are attached to the outside of the tube. The caps are attached such that when the servo rotates, so does the cap. The servos can then control the opening and closing of the top and bottom of the tube.

Using this simple mechanism, the strategy is three-fold: the robot starts with the ABS tube (the passive acoustic sensor) inside our module. The simulation sensor is made up of two 30 cm lengths of black ABS tubing connected by thick chain, and one tube is packed with flotation to make it positively buoyant. The module tube has a notch cut out at the bottom so that non-buoyant length of the sensor can sit inside the module tube, with the chain feeding out through the notch, letting the buoyant sensor tube float outside of the module. The ROV will then drive to the appropriate deployment area, drop off the acoustic sensor, and continue on to collect the biological specimens. The O-ball is collected first, which will be on the pool floor to save travel time (the ping-pong balls under the ice will be retrieved on the way back up to the surface). When the O-ball is sighted on one of the onboard cameras, the bottom cap of the module is opened, position the ROV so the module container tube is on top of the O-ball. The robot will then drive down over the O-ball, capturing it inside the tube, and finally swing the cap closed over the module. Now, the vehicle can drive freely with “jellyfish” in tow. Next the vehicle can start its ascent back to the surface, stopping on the way to collect a ping-pong “algae” sample. This time, the module’s top cap will swing open. Then the vehicle will hover below a mass of ping-pong balls, drive up, hopefully capturing one in the module tube, and swing the cap back closed, encapsulating the ping-pong ball inside the module along with the O-ball. Once the three tasks are completed the ROV can return to the surface.

Mission 3

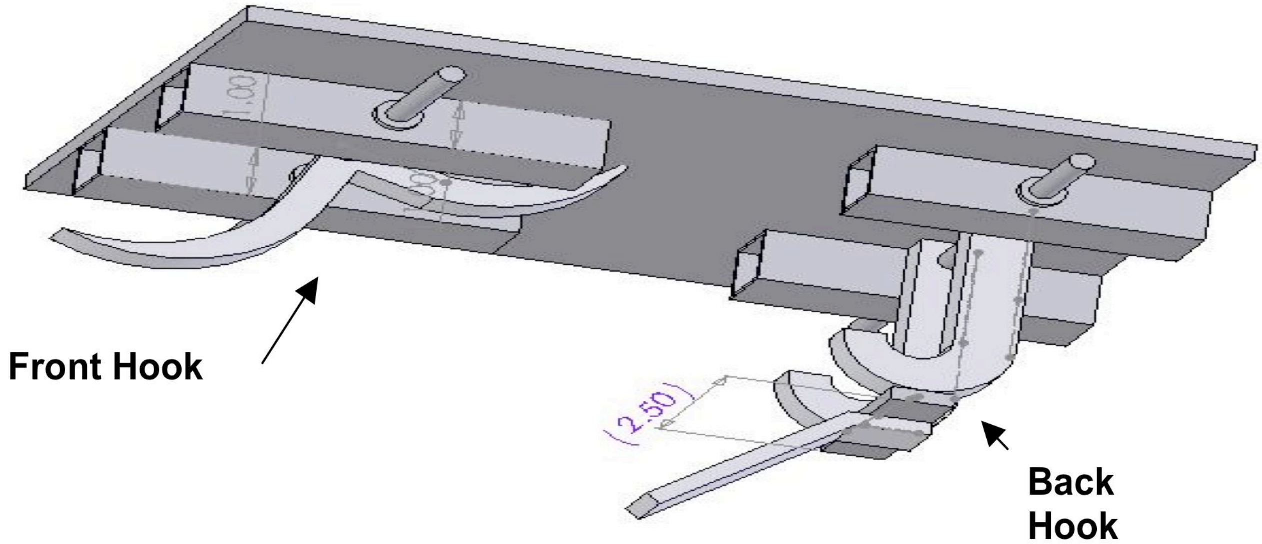

Figure 2 - Original module three design

The third mission for the 2007 MATE ROV competition consisted of putting a gasket into a tube and then inserting and removing a hot stab.

The third module went through three different incarnations before settling into its final form. Figure 2 shows the original design for module three. The design made use of two of servomotors. The gasket will be carried down to the mission apparatus suspended on the back portion of the double hook in the front of the module. The cap of the wellhead will catch on the front portion and then be removed when the servo rotates. When the servo is has finished rotating, the gasket will fall off of the hook and into the wellhead. Once the servo rotates one last time, the cap will slide off the same way that the gasket did. The "T" portion of the hot stab will rest in the dual hooks at the rear of the module. The T-shaped piece connected between the hooks is intended to support the hot stab at a 45°. In this version, the back hooks were rotational (as you can see from the rod from which they are suspended), which was intended to increase the tolerance as the hot stab enters the pipe.

In order to test this design before building, simple calculations were performed to confirm that the cap and the gasket would sink, and the servo would have enough torque to lift the cap. In order to check that the cap would sink, the components masses were determined. The cap is made of PVC (density of 1380kg/m^3) while the u-bolt is made of iron (density of 7000kg/m^3). The volume that the PVC takes up is the same as the volume of the top of the cap plus the volume of the sides, as shown in equation 4.

Then the u-bolt at the top of the cap has a volume of its total length times its cross sectional area, as shown in equation 5. The total mass was then determined by multiplying each density by each volume. The volume for the cap was 102.9 cm^3 and the bolt was 8.275 cm^3. The total mass of the cap assembly was .2 kg.

$$V_{Total} = V_{top} + V_{bottom} = \pi r^2 t + 2\pi rtL \quad (4)$$

$$V_{bolt} = \pi r^2 L \quad (5)$$

In order to determine whether or not the cap sinks, the mass of water displaced must also be determined. The density of water is 1000kg/m^3, so the mass of the displaced water is .11 kg based on the volumes from equation 4 and 5. Thus, the cap will sink, because the mass of the cap is greater than the mass of the water displaced.

Next, the sinking of the gasket was analyzed. The gasket is made of a ring of rubber (density 1100kg/m^3) with an inner radius of 3.8 cm, an outer radius of 5.1 cm and a thickness of 6.4 cm. The volume of the rubber was found to be 22.45cm^3 from equation 6. The total mass was found to be .073 kg from the rubber with a mass of .0247 kg, the screws with a mass of .023 kg and the rope with a mass of .0014 kg.

$$V_{rubber} = \pi(R_{outer}^2 - \pi R_{inner}^2)t \quad (6)$$

The mass of water displaced is .0671 kg found from equation 7. Again, the calculations show that the gasket will sink. The sink will occur only in the vertically downward direction because (as per the instructions) the current near the mission props is negligible. Thus the assumption can be made that the props will rest on the bottom of the hooks.

$$M_{displaced} = (V_{gasket} + 2V_{screw} + V_{rope})\rho_{water} \quad (7)$$

The torque required is .0332 N-m, from equation 8, which is well in line with the amount of torque supplied by the servos. The front module could then be built based on the success of these design checks.

$$T = F*d = (\text{weight cap- force of buoyancy})\ (\text{distance}) \quad (8)$$

One design change was found after the initial building of the back hooks. It was recommended that a compliant mechanism was designed for the back hooks, so that as the hot stab was inserted, the mechanism could alleviate of the alignment issues of maneuvering, as shown in Figure 4. The cylinders are pieces of PVC pipe with springs attaching the circular plate to the base plate suspended inside the pipes. The hooks are attached to the base plate via screws.

To find the desired spring constant K of the springs, equation 9 was utilized. The ROV is capable of generating 10 N of thrust. For this first order calculation, the force of this thrust can be approximated as being distributed equally among the three springs, so each will feel a maximum force of 3.33 N. At maximum thrust, the ROV should be able to move no less than an 2.5 cm away. By solving equation 9 for the spring constant, a K value of 131 N/m was used. For the purposes of ordering springs from McMaster-Carr, the spring, as shown in Figure 3, requires .748 lbs to expand one inch.

$$F = Kx\ (\text{hooke's law}) \quad (9)$$

Figure 3 - The Springs Used for the Compliance Mechanism

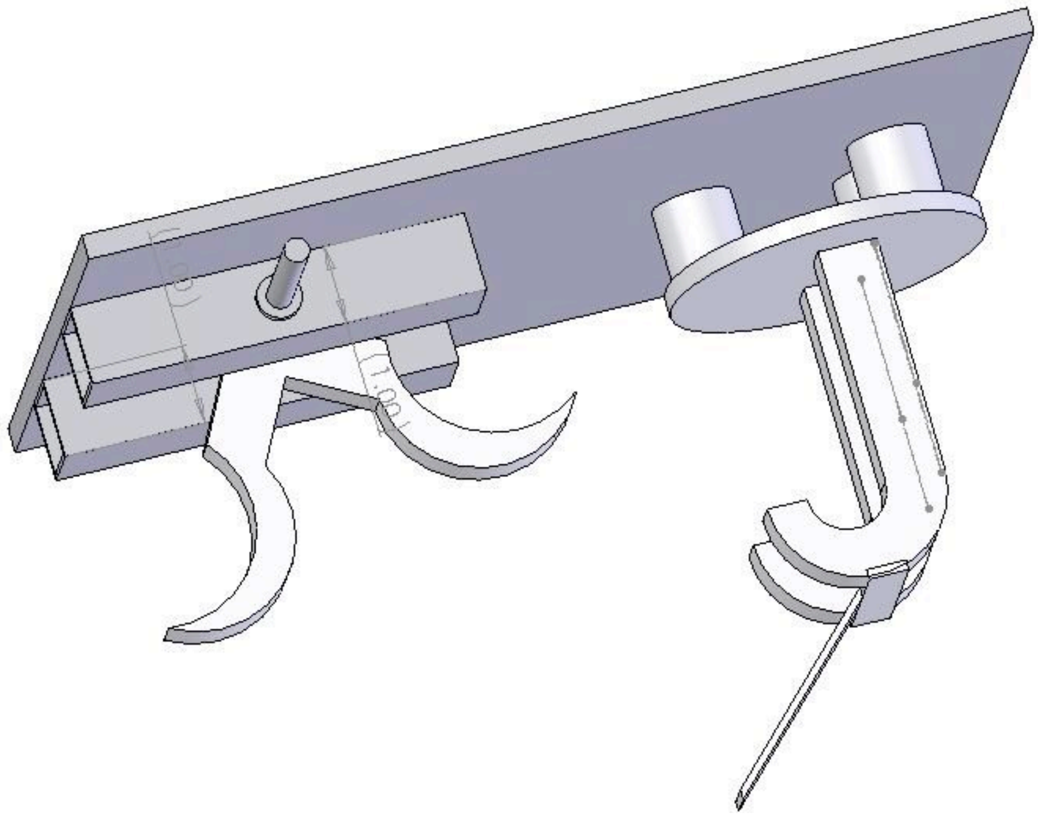

Figure 4 - Final design for the third module

Frame design

There are two major issues that needed to be addressed in a modular design that result in contradicting requirements. First the interface between the frame and the modules has to be as generic as possible in order not to restrict the functionality of the modules. On the other hand the performance is critically dependant on the dynamics of the vehicle. So to achieve a reasonable performance the modules must not significantly alter the overall structure of the vehicle and its dynamic characteristics.

The frame design represented a critical step in setting the requirements for all the modules, so it was the first on which detailed design started. This combined with the range of ways to address the problem of interconnecting parts in a modular design – from very strict interfaces to almost completely ad hoc solutions – resulted in a number of iterations before a final design was accepted.

With the above problems considered a design was developed that was closer to a "traditional" ROV style. The requirement that the modules be easy to attach and remove from the frame was maintained but no strict interface for connection was used. The only real design parameter was to leave enough surface area on the frame capable of providing a structural support for the modules and designing the actual attachment of the modules as they develop. The result was a "box-like" frame surrounding the control box and the batteries as shown in Figure 5.

This design allowed for a much more compact structure than the previously iterations, reducing the bending moments inside the structure. Both the side plates and the connecting struts provide space for mounting modules. A clear disadvantage of the design is that modules are not as readily interchangeable but might need to be attached at a specific point on the frame, thus causing some interoperability issues. Also because of the size of the vehicle only a small number of modules can be accommodated at a time anyway. Both of these are not so serious issues currently as the vehicle is focused mainly on the competition, but as the vehicle is implemented in future expeditions, these design choices may prove to hurt the operation of the robot.

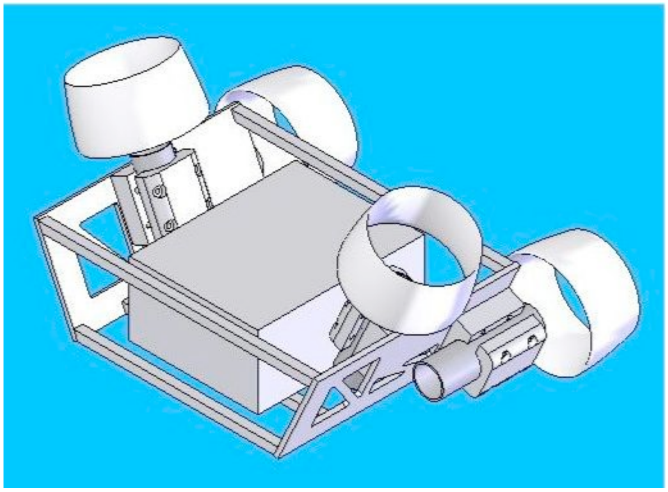

Figure 5 - Final frame design, including thrusters and control box. Modules are to be attached to the struts connecting the two side plates.

Thrusters

Instead of completely redesigning the thrusters from the year before, the design and the components of the previous year's thrusters were used. This decision was two fold. First, the team had lost a large quantity of its seniors, so the team decided to focus on learning and improving the old design instead of work in completely new territory. Second, the thrusters from the year before had a critical design flaw.   The shaft from the motor was unconstrained, so the flexi-seal leaked after they had been damaged in shipping. The problem was fixed by reworking the entire end cap such that the shaft of the motors passed through roller bearing sets before it reached the props. Thus the thrusters would be able to be fully constrained in all degrees of freedom except for the rotational axis driven by the motor.   By iterating instead of re-starting, the thrusters should present a much lower risk than they did in years previous

Batteries and Tether

This year, the MIT ROV Team again chose to utilize a fiber optic tether with a Ni-Cd battery pack.   The fiber optic tether has shown to significantly reduce the drag in the vehicle, while still maintaining the ability to receive all of the data necessary to operate the robot. The team has learned from its past and will be using a jacketed tether instead of a fine strand of fiber.   The jacket hopes to provide the stiffness and protection such that the line is not pulled into the props or other machinery. In addition, the new-jacketed tether hopes to provide a stronger connection between the top side and the robot, such that an operator on the deck can manage the tether and keep it out of harms way.

The battery pack this year was custom built to house the teams ten Ni-Cd batteries. Alternative batteries were explored, but the Ni-Cd remained the most cost effective versus their energy density. Lithium polymer batteries remain out of the reach of the team for now. A new battery housing was built for the batteries such that no soldering will be required. In the past, the experience of soldering each of the batteries together has led to failures because of the fragility of the solder connections. For this year, a PCB back plane was built with leads on it to connect and constrain the batteries, so that solder joints will no longer be required. The batteries will then be stored in a space efficient container.

Bottom-Side System Architecture and Electronics

The schematic layout of the control system, grouped by functional subsystems, is shown in Figure 6. The fiber modem is at the top in a filleted rectangle, while key subgroup components are in square-cornered rectangles. Input and output devices are in white ovals. The type of arrow indicates the type of signal: dotted lines for communication, solid lines for power signals, dashed lines for video, and alternating dot-dashed lines for PWM.

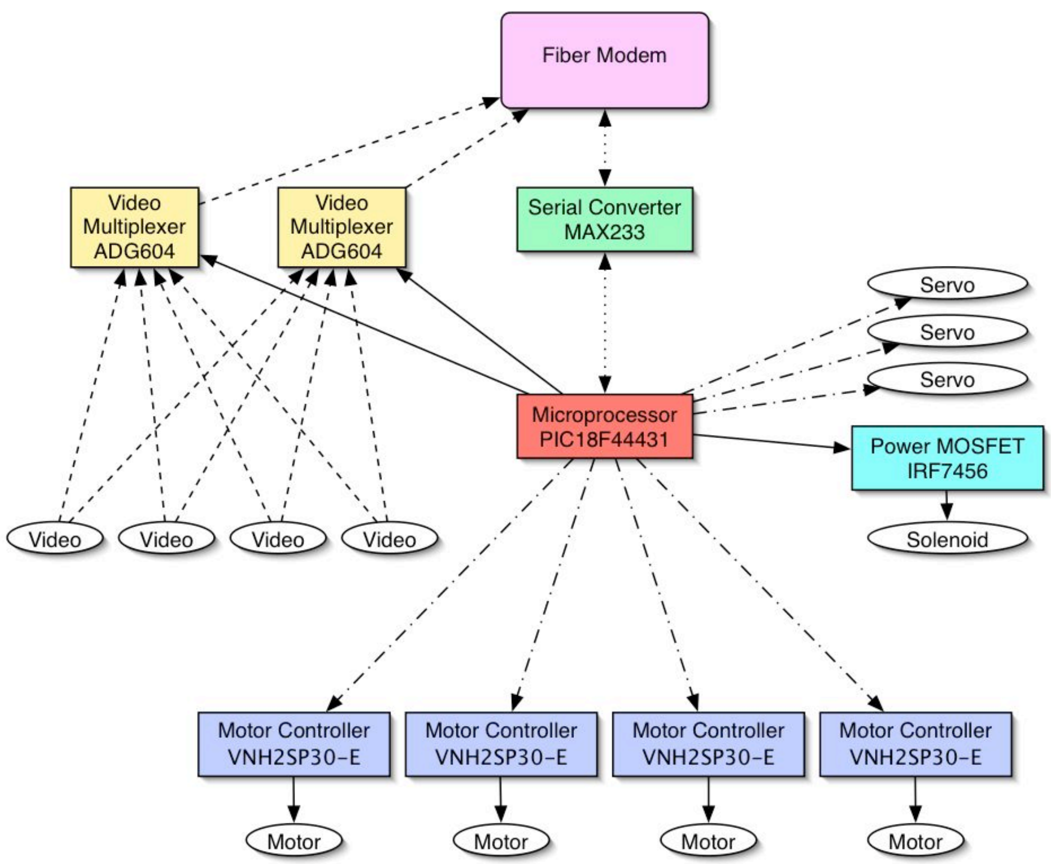

Figure 6 - Block diagram for the components of the bottom-side control system

The first objective was to try to fit all of the electronics into as small of a package as possible. Because of this, the smallest package of each microchip was chosen. Almost all components are surface mount except for connectors and large heat-dissipative components. This makes it possible to place components on both sides of the board in the same coordinate, allowing for maximum space efficiency despite increased assembling difficulties.

With an overall size set, each of the components was chosen to meet the requirements of the robot. The processor is central point of the control board since all signals pass through it (see Figure 6). The Microchip PIC18F4431 was chosen as the processor for the control board due to its features that are geared towards robotics and motor control applications.[2] It has an 8MHz internal oscillator, 9 channel 10-bit analog-to-digital converter, 8 PWM channels, built-in motion feedback control, and ample memory for program storage. The 44-pin thin quad flat pack (TQFP) footprint was chosen for its small size (see Figure 2, component U1), and it communicates via an RS-232 serial channel.

The topside computer communicates through transistor-transistor logic (TTL), while the PIC communicates through RS-232. Therefore a Maxim MAX233 multi-channel RS-232 driver is used to ensure successful communication between the computer and the PIC.[3] The footprint chosen is a 20-pin small outline integrated circuit (SOIC) instead of a bulky 20-pin plastic dual inline package (PDIP). Multiple light emitting diodes (LEDs) indicate the transmit and receive status for communications debugging.

Four STMicroelectronics automotive H-bridge VNH2SP30-E motor driver power the four thrusters.[4] The motor driver comes in a MultiPower-SO-30 package, which is a surface mount small outline package with thermal heat pads on the bottom. The motor driver can supply up to 30 amperes each so there is no danger of overheating using our 6 ampere thrusters. It is controlled by PWM signals, which the PIC can readily output. The traces that connect to the thruster are very wide because they must handle the large current.

Since the PIC can directly output PWM signals, only a trace is necessary to connect to the header that connects to the servo. The other header lines in Servo1, Servo2, and Servo3 are connected to ground and 5 volts. An International Rectifier IRF7456 MOSFET that supplies up to 16 amperes at 20 volts controls the solenoid.[5] The MOSFET is used as a switch controlled by the PIC that allows for high current to flow through to the solenoid. Since the solenoid is a large inductor, back-EMF may be induced once the MOSFET is turned off, so to avoid reverse voltages across the MOSFET caused by turning the solenoid off, a draining diode is placed in parallel with the solenoid. This diode is an International Rectifier 18TQ035 that handles up to 18 amperes at 35 volts. When the MOSFET stops supplying a voltage to the solenoid, the existing current in the solenoid passes through the diode and eventually dies out from the internal resistance.

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[2] http://ww1.microchip.com/downloads/en/DeviceDoc/39616b.pdf
[3] http://datasheets.maxim-ic.com/en/ds/MAX220-MAX249.pdf
[4] http://www.stmicroelectronics.com/stonline/products/literature/ds/10832.pdf
[5] http://www.irf.com/product-info/datasheets/data/irf7456.pdf

In order to switch four channels of video, two Analog Devices ADG604 4-channel multiplexers were chosen.[6] The ADG604 uses two inputs in binary to determine which of the four video inputs is to be fed to the video output. Since both ADG604 chips are connected to all four video channels, they can be independently switched to show any of the four video feeds. The ADG604 comes in a 14-lead thin-shrink small outline package (TSSOP), and operates off of the 5 volt source on the board (see Figure 2, U4 and U5). SMB connectors are used for video inputs and video outputs due to their small footprint and coaxial nature.

In case of an emergency, a master kill switch can be toggled off to shut down all electronic components. This is done by passing the input 12 volt power through an International Rectifier IRF3704 HEXFET.8 The HEXFET can handle up to 77 amperes at 20 volts, and has a gate threshold voltage of just 1 volt. The gate of the HEXFET is connected to header, which can be connected to a switch sourced at 5 volts. A hall effect sensor can be connected to the header to allow for through-hull disabling of the vehicle. For bench top testing purposes, a jumper can easily be placed onto the header instead. An LED is placed between 5 volts and ground to indicate power status.   A 25-ampere fuse is also included between the 12 volts in and the 12 volt rail of the board.

Finally, all of the components were assembled onto a PCB. The original routing of the board involved six layers: two signal planes, two ground planes, a 12 volt plane, and a 5 volt plane. This was to reduce the board to contain signal traces only. However, the price for production of a six layer board was far out of the team's price range, so the board was redesigned to four layers: two signal planes, a 12 volt plane, and a ground plane. This way, only lower voltage (5 volt) traces contained power. This is the current version of the board, as seen in Figure 7. The full electrical schematic for the underwater system is provided in the included appendix.

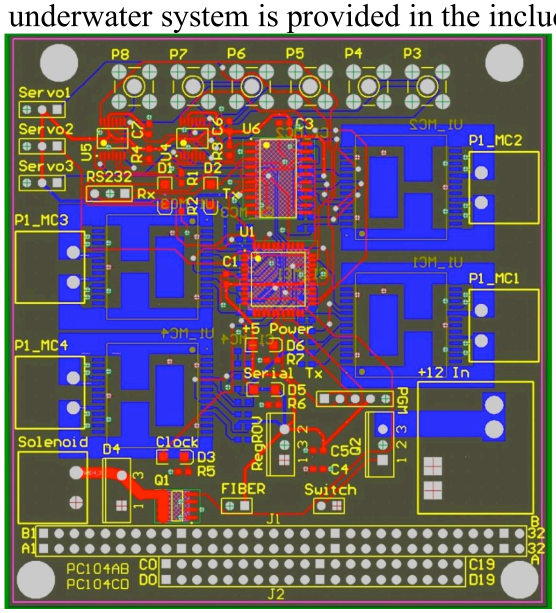

Figure 7 - Board layout for four-layer PCB

[6] http://www.analog.com/UploadedFiles/Data Sheets/ADG604.pdf

Software

The topside control for this year's robot is using the same software from the year before with a new twist. Instead of being controlled by joystick, the robot will now be able to be controlled via a Wii remote, hence the name WiiBot I. The Wii remote will output values relating to the pitch and tilt of the remote, and then the software will convert these into motor commands for the robot. The result will be that an operator will not need to be connected directly to a dash board or a table to run the robot, but can sit or stand and control as they please. In addition, these new axes of control hope to provide a much more complex platform on which to manipulate the robot.

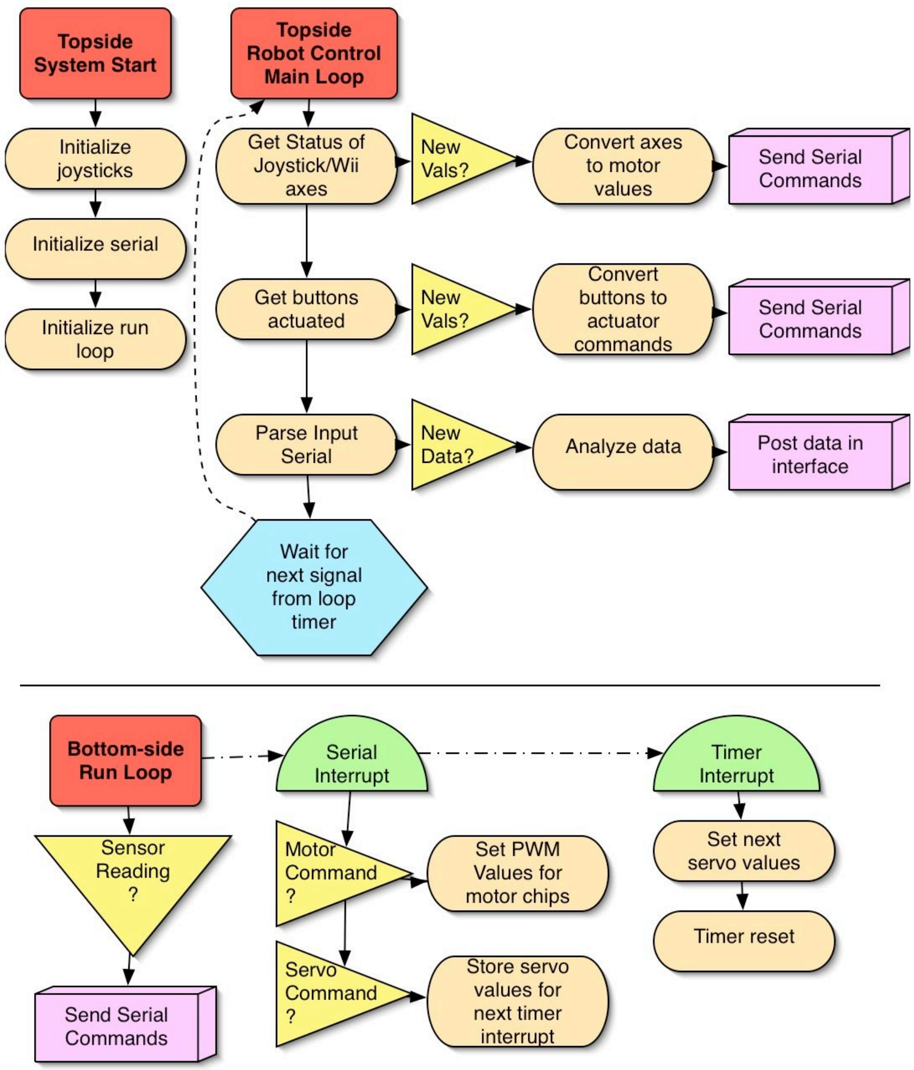

Figure 8 - Flow diagram for the topside and bottom-side software

In addition to the Wii development, the rest of the software also received a major upgrade this year to become much more robust, represented in Figure 8. First, the software now operates on a fixed set of outputs. The controller can command four thrusters, three servos, two solenoids, and two camera switchers. Based on the years of experience for the team, this should provide more than enough freedom to control the robot. Future expandability can be built in as required to accomplish more complicated tasks. On the microchip, new software was installed that provides a much more robust interface. The microchip can now reset itself in a low voltage situation or a stall in the code.   Brown out and watchdog timers have been implemented such that no matter what happens, the microchip will keep trying to start up after a fault.   The result is a robot that will work through hiccups, and provide a steady operation throughout the competition.

Inertial Navigation System

Inertial Guidance Systems come in two flavors, gimbals stabilized systems and strap-down systems. Stabilized systems use gyroscopes to stabilize the platform on which the rest of the system, basically accelerometers, lies. Strap-down systems involve rigidly attaching these chips to the vehicle's frame. In general, strap-down systems are much easier and cheaper to implement. Furthermore, they have some obvious advantages over a gimbals stabilized system in that they consume less power since they do not have to use motors or momentum wheels to maintain stability. One also does not have to keep track of inefficiencies in the motors and gyroscopes used to keep the platform stabilized, in addition to the drift characteristics of the actual inertial measurement unit itself. We therefore decided to concentrate on the development of a strap-down system for the team's robot.

The team implemented the strap down system to provide navigation to the robot pilot. The accelerometers and gyroscopes used are of the Micro Electro-Mechanical System (MEMS) type, since such chips are cheap and generally robust. The sensors used are theADXL330KCPZ (Tri-axis accelerometer), ADXL103CE   (Single axis accelerometer), and ADXRS401ABG (Tri-axis gyroscope) microchips as shown in Figure 9.

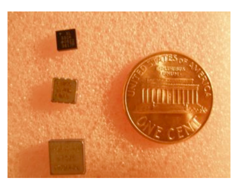

Figure 9 - Inertial Navigation System

A magnetic compass is used for initial system calibration and secondary heading information only, since it can be adversely affected by the presence of ferro-magnetic substances. The sensor used is solid state and triple-axis magnetic field sensor made by Honeywell, the HMC 1043 as shown in Figure 10.

Tilt compensation is provided using vehicle pitch and roll information from a twin-axis accelerometer. A separate accelerometer is used from the ones in the Inertial Navigation System for redundancy. The full system integration is shown in Figure 11.

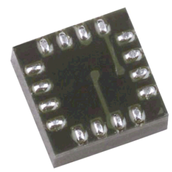

Figure 10 - The HMC 1043

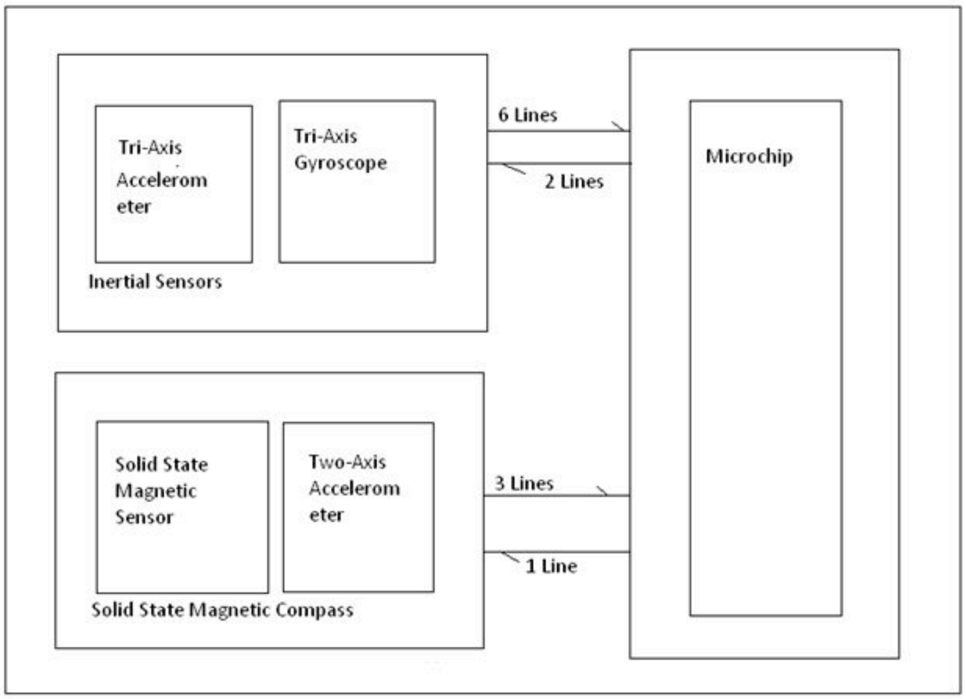

Figure 11 - Block Diagram for Inertial Measurement Unit Prototype

Team Challenges and Trouble Shooting Technique

Our team was faced with many challenges. As we successfully overcame these challenges, our camaraderie and confidence increased. One of the most difficult and drawn-out problems was the design process of the Mission One apparatus, designed to pass a cord through an eyelet. The original design was simple and elegant, and we were fairly confident that it could be implemented without great difficulty. Though in the end the design proved very successful, the road to success was paved with difficulty.

The way that we overcame these difficulties was through methodical and deliberate trouble-shooting. In the first prototypes, several design flaws were noticed, such as the frequent misalignment of the magnets, which hold the device together. We analyzed the problem and decided that keeping the magnets in better contact with each other might solve the problem, so a flexure was implemented. This innovation improved the design of the device, but did not entirely solve the problem. Therefore a set of notches at the magnet contact points was implemented to maintain magnet alignment. After the flexure was implemented, the device broke easily when dropped or mishandled. We found that a simple change in the material the device solved that problem. The glue that held the notches and the magnets to the plastic had a problem with becoming weakened from use and stress. Several glues were tested for different properties, and one was selected which successfully maintained the structural integrity of the device.

An important element of the design of the device was its ease of manufacture. Our trouble-shooting was successful because we were able to make many prototypes of the device and refine its design. By carefully considering how design problems might be handled and trying many variations, we were able to arrive at a device of which we are confident and proud.

Lessons Learned – by Stephanie Chin

When I first joined the MIT ROV team, I expected to be "just a freshman," on the outskirts of the project, watching the action until someday I, too, would become an Important Member of the team. I was thoroughly surprised, then, when each of the three freshmen was appointed lead on one of the three missions. I would actually be doing tangible work?!

Following through on an entire subsystem project was an invaluable experience. Not only did I learn the basics of electronics and controls through various workshops the upperclassmen put together in the beginning of the year, but I continued to learn important pieces of information throughout the entire design and build process. I learned how to calculate what type of servo we needed, how to properly implement motors without damaging them, and how to model using SolidWorks. The team was always there to brainstorm with me, make suggestions, and guide me when I had no clue what I was doing.

I also gained experience with machine tools, and learned that you should always think about what you are cutting/ drilling/ tapping before you actually do it, especially when your material is limited. I saved myself a lot of frustration by simply making sure that cuts made sense, but I also had to re-drill a few holes because they were slightly off.

I learned that you should keep the design as simple as possible, because the actual assembly and attachments can turn out much more difficult than it seems. To that end, it is always helpful to talk to someone more experienced who might have already attached similar parts for a similar purpose.

I am grateful to be building a robot with a team that so actively encourages me to participate, learn new skills, and follow through on projects.

Future Goals

Short-Term

The production cost for a four-layer board is still unreasonable for a part that is not guaranteed to work. Therefore, the board will be redesigned to two layers, requiring tricky part placement and manual trace editing. However, the cost savings will be enormous since the cost of a two layer board is one-twentieth the cost of a four layer board in the same turnaround time. If it is unfeasible to create a single two-layer board that contains all of the components, the capabilities for boards of the PC104 form factor to stack makes it feasible to design two separate two-layer boards that accomplish the same tasks. Design has been temporarily halted due to an expired license for Altium Designer, but that is being sorted out as soon as possible.   In addition, the team hopes to use this year's robot to provide a platform for testing many of the new modules implemented. Once the competition is over, complete testing of the control system, the thrusters, the manipulators, and the tether will be completed to generate data for developing future designs.

Long-Term

There has been speculation about acquiring new batteries with higher energy densities, such as lithium polymer (LiPo) batteries. If we do end up using these batteries, the output pack voltages will probably be different from the NiMH batteries. Therefore different voltage regulators may be necessary to enable proper chip functionality. The team also has started to look into performing tasks outside of the competition, from simply getting in real water and looking around to performing complex maneuvers in real conditions. Lastly, the team is beginning to look into outreach and how to bring the world of robots to students in the Boston area. One example was participating in the Cambridge science fair, but hopefully future experiences will be possible.

Culture At The Poles: The Inuit Societies

The people of the Arctic have traditionally been called Eskimos by outsiders, but prefer the term Inuit. A very scattered population, they are united across arctic Canada, northern Alaska, Greenland, and some would argue parts of Russia, by a common cultural heritage and a common language. The first Inuit are believed to have migrated from Eurasia via the Siberian land bridge. Originally, they were almost exclusively based in northwestern Alaska, where they specialized in hunting large aquatic mammals, especially whales. This lifestyle offered an advantage over other land hunting lifestyles because even a small whale could weigh seven tons and consequently a small hunt could provide sustenance for quite some time. About a thousand years ago, the Inuit began to spread east into Canada, replacing an earlier population known as the Tunit. The actual migration seems to have been composed of groups of 20-30 people moving east in search of the good whaling territory near Baffin and Somerset Islands, much like an inverse of the American move westward in the 1800's. Around 1300, temperatures began to drop and the Inuit were forced to move southward, abandoning the rich whaling grounds and their relatively comfortable lifestyle. As their habitat became sparser, the advanced houses constructed from sod and whalebone were no longer built, but instead houses made of blocks of snow, igloos, became popular. The Inuit first came in contact with European Explorers from the voyages of Martin Frobisher in the 1570s and the search for the missing rankling expedition in the 1850s. There were many expeditions to the Arctic, mostly from England, because there was a great interest in finding a Northwest Passage from the Atlantic to the Pacific, which would have benefited trade. The Europeans neither attempted nor succeeded in gaining anything from the meeting, but they did bring iron, which was used by the Inuit to make harpoon points and knife blades. In the 1850s, the whaling industry experienced a boom and many Inuit were hired to work on ships as hunters or seamstresses. These individuals brought a broad range of western goods into Inuit daily life, and the increased ship traffic in the Arctic meant that as many as 15 crews per season became involved in the life of a village. Contact with the whalers also brought diseases, to which the Inuit had no immunity. The population of Inuit in the Canadian Arctic fell from 2000 in 1850 to 150 in 1910.   By the turn of the century, the whaling industry was collapsing, so the whalers turned to fur for their livelihood. The post-WWI fur industry led to the influx of the Royal

Canadian Mounted Police and the Church. By 1925, the Inuit were not quite citizens of Canada, but functioned as its subjects. Missionaries caused the disappearance of many traditional customs and many Inuit became impoverished because of fluctuations in fur prices. After WWII, the Canadian government began to be interested in Inuit affairs, encouraging them to give up their nomadic way of life. Cheap housing, schools, medical facilities, and modern stores were built. This trend led to more problems, however. Without making a living from the land, the Inuit were extremely dependent on social services and jobs were hard to obtain in communities full of Inuits all in the same conditions. The sixties brought many changes for the Inuit, the Northwest Territories began the process of becoming a province, and "Eskimo Co-ops", which would eventually lead to the foundation of the Inuit Brotherhood and finally the creation of a predominantly Inuit territory called Nanavut in 1999.[7]

It has been assumed that the because the Inuit eat such a high fat, high cholesterol diet and have a comparatively low incidence of heart disease, that they must have some genetic adaptation which makes them immune, but the latest theory is that because the fats they eat are predominantly omega-3 fatty acids (the "good" fats) that their diet is just healthy. However, a large portion of the Inuit cannot digest the sugar sucrose, due to low activity of the sucrase enzyme in the small intestine, which is believed to contribute to the high rate of obesity among the Inuit. This obesity is also partially the result of a "thrifty" genotype. The theory is that the pressures of evolution favored individuals who were able to maintain their fatty tissues even in times of great privation. Today, however, these genes are not needed and people with them become obese. High incidence of obesity is related to high incidence of diabetes mellitus. Today, there is much interest in returning to "ancestral eating patterns" as a way to combat these phenomena.[8]

Reflections on the Experience

On April 28, 2007, the MIT ROV Team participated in the first annual Cambridge Science Festival. Over 200 children from the area visited up our station, which was at one of MIT's pools and the ages of the children ranged from four to twelve. The exhibition provided the team an opportunity to show our ROV to them. We set up for the children a simple ROV called a Sea Perch inside the pool. The Sea Perch had one upward propeller to provide the vertical motion and two propellers which were angled slightly outward to provide the horizontal motion. The Sea Perch was connected via tether to an external power supply and a control box containing two push buttons for the vertical propeller and two toggle switches for the two horizontal propellers. The children were given an opportunity to pilot the Sea Perch for approximately two minutes. While they were driving, we also took time out to explain to them how the Sea Perch and some of the issues associated with robotics and ROV such as buoyancy, motion, power, and water protection as well as answered any questions that they had. The experience definitely provided us with a chance to pass along our enthusiasm about robotics and ROV and also gave the children an opportunity to experience how exciting and amazing robotics, ROV and engineering are.

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[7] Morrison, David. "Canadian Inuit History: a 2000 Year Odyessy." Civilization.CA. Canadian Institute of Civilization. 20 May 2007

[8] Stinson, Susan. "Nutritional Adaptation." Annual Review of Anthropology 21 (1992): 143-170. JSTOR. MIT Libraries, Cambridge, MA. 20 May 2007.

The day, however, was not without problems. After testing the simplistic Sea Perch in the water several times, everything appeared to be working and normal. But after the first several children piloted the Sea Perch, one of the angled side propellers came off. Initially we tried screwing it back on, but we achieved the same disappointing results. After examining the propeller, the team realized that the hole for the screw had a crack and had become larger. Eventually, we were able to get a new propeller to fix that propeller. Unfortunately, that was not the end of our problems with propellers and by the end of the day, we had to replace all of the Sea Perch's original propellers. The experience provided the children a few important lessons about engineering. First, they were able to learn that even if designed correctly, systems, such as the ROV can have errors due to things such as the wear and tear that occurred to our propeller. Additionally, our process of dealing with the problems we encountered demonstrated the resourcefulness needed in dealing with issues in engineering and also how to generate solutions for unexpected issues.

Acknowledgements

All the members of the MIT ROV Team would like to thank our sponsors and advisors for their support, without which we would not be able to continue our hands-on education in marine robotics.

ExxonMobil

Prizm Advanced Communication Electronics

Altium

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MIT Department of Mechanical Engineering

MIT Sea Grant College Program

The Edgerton Center and Student Shop

Fiber Instrument Sales, Inc

The Ocean Engineering Design Lab

The Ocean Engineering Teaching Lab

Dr Franz Hover

Christiaan Adams

Dr. Rich Kimball

Budget

MIT ROV Team Expense Sheet FY 2007

Team Expenses

ROV		
	Frame	$ 97.24
	Electronics	$ 81.90
	Case	$ 49.96
	Assembly	$300
Research		
	Mission 1	$ 3.56
	Mission 2	$ 155.44
	Mission 3	$ 223.12
	Control	$ 39.99
	Other	$ 25.39
Media		
	Poster	$200
	Paper	$100
	T-Shirts	$ 274.95
Travel		
	Lodging	$ 400.00
	Shipping	$500
	Rental Van & Airfare	$4,416.00
Food		$ 206.65
Total Expenses		$7,074.20

Resources

Monetary				
	MIT ME Contribution			$3,000.00
	MIT COE Contribution			$3,000.00
	Exxon Mobil Contribution			$5,000.00
Total monetary resources				$11,000.00
Other				
	Altium			
		CircuitMaker		$12,000.00
	Analog Devices			
		3 Single axis Accel.		$23.25
		Gyroscope Eval Board		$5.45
		Tri-axis accelerometer		$59.95
		Tri-axis Accel Eval kit		$22.00
		Gyroscope		$50.00
Total donated items				$12,160.65
Re-used Items				
	Cameras	200x3		$600.00
	NiMH batteries	22.65x20		$453.00
	Thrusters	505.51x4		$2,022.04
	Tether			$53.30
Total re-used items				$3,128.34

Appendix – Electrical Schematics

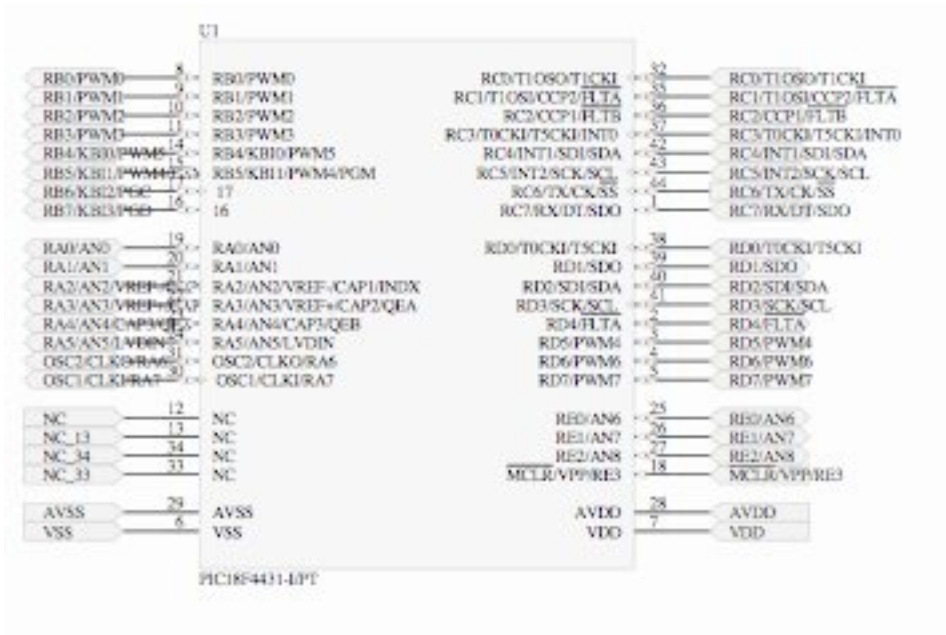

Figure 12 - Microchip IO

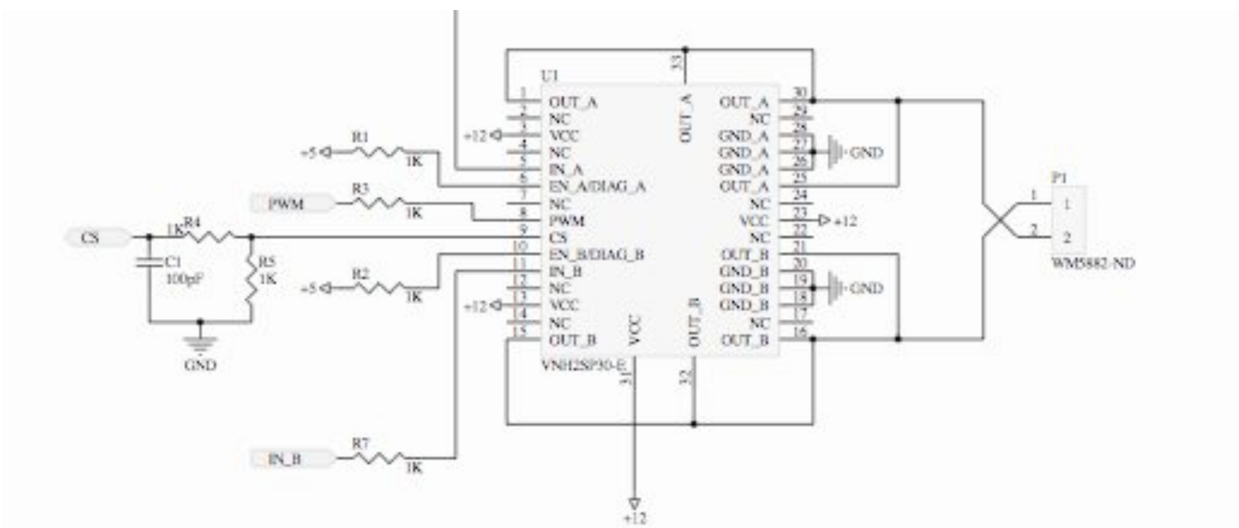

Figure 13 - Motor chip schematic

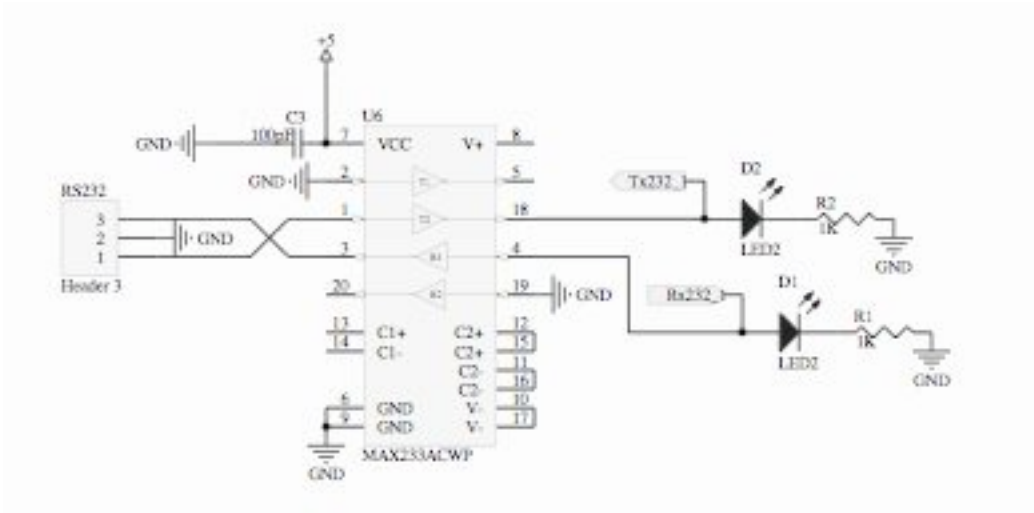

Figure 14 - Serial to TTL converter schematic

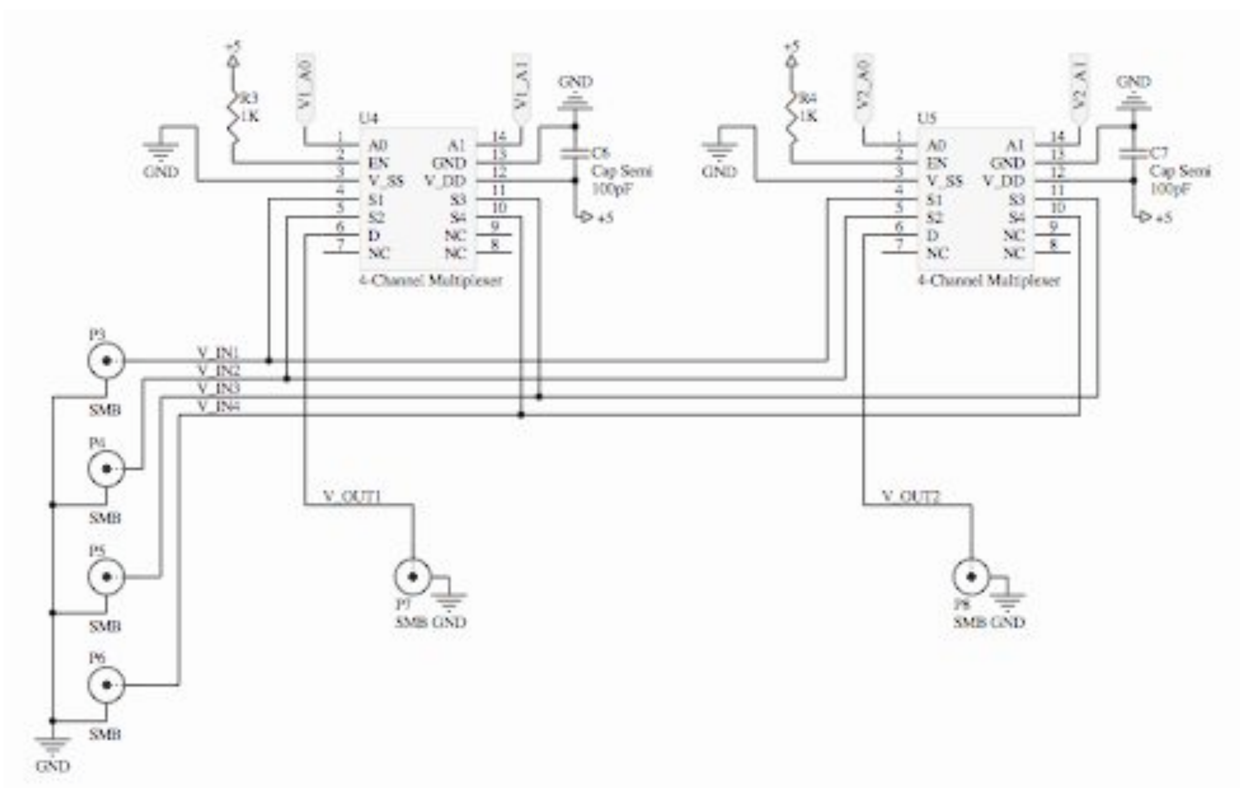

Figure 15 - Video switcher schematic

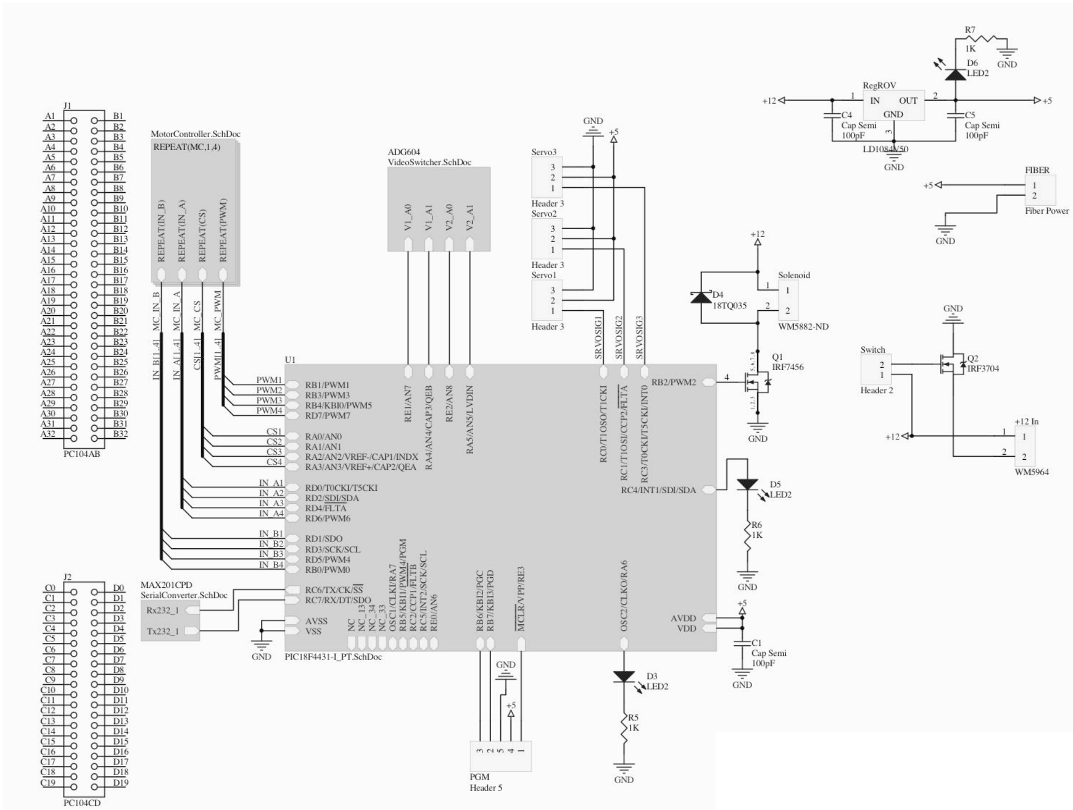

Figure 16 - Overall chip schematic