

Hawaii 808 Ninjas

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Abstract

Katana was designed to complete the missions planned for the 2011 MATE Big Island Regional (BIRR) Remotely Operated Vehicle (ROV) Competition. Individual experience brought to the team allowed us to create effective tools. A claw was designed to turn the wheel to shut the oil flow off, carry the hook used to attach to the damaged riser pipe, undo the velcro to “cut” the damaged pipe and transport the hose line from its holder to the well. A hook is attached to the front of the ROV, near the claw as a backup tool and carries the well cap down to the bottom of the pool. A grappling hook, designed to insert into the u-bolt, allows the person working the tether to bring it up. The pressure sensor on board the ROV, allows the pilot to determine if he is at the correct depth to collect a water sample. The last tool on board the ROV is a series of hard drive magnets that are zip-tied to a net on the bottom of the ROV. They collect the sea creatures which all have magnetic properties.

The cameras and motors used on the ROV are all new. Vertical thrusters use 1250 gallons per hour (GPH) bilge pumps while the horizontal thrusters are 500 GPH bilge pumps. Due to previous waterproofing issues, different cameras were used this year. Also because the team wanted to use new thrusters with different power than before, new motors were ordered.

Budget

Item	Quantity	Cost	Donation	Paid	Source
1/2" PVC Pipe	~20 ft	\$12	\$12	\$0	Central Supply
1/2" PVC Fittings	\$16	\$10	\$10	\$0	Central Supply
Aluminum Pieces	Various	Scrap	\$0	\$0	IFA
Controller Board	1	\$225	\$225	\$0	HIEDB
500 GPH Motors	2	\$15	\$30	\$0	ROC
1250 GPH Motors	5	\$29.99	\$0	\$176.70	West Marine
Propellers	4	\$15	\$60	\$0	ROC
Pin Hole Cameras	3	\$12	\$36	\$0	ROC
2x4" Aluminum Tube	1	\$40	\$0	\$40	Hilo Steel
Monitors	4	\$35	\$35	\$105	Target
H-Bridge Amplifiers	1	\$65	\$0	\$65	Jameco Electronics
Connectors	2	Salvage	\$0	\$0	IFA
35:1 Mini Metal Gear Motor	1	\$40.85	\$0	\$40.85	Pololu
Plastic Gears	2	\$9.95	\$0	\$22.89	RC Planet
Monitor Case	1	\$25	\$0	\$25	Home Depot
Home Depot Gift Card	1	\$0	\$100	\$0	BIRR Competition
Lowe's Gift Card	1	\$0	\$50	\$0	ROV International Competition
Miscellaneous	Various	\$30	\$0	\$30	Home Depot
Lynxmotion Motors	2	\$21.95	\$0	\$43.90	Robot Shop
Cytron Gearmotors	2	\$15.48	\$0	\$30.96	Robot Shop

	Income	Expenditures
Home Depot Gift Card	\$100	\$0
Lowes Gift Card	\$50	\$0
Camp Eureka: ROV Edition	\$1,100	\$0
ROV Materials	\$0	\$579.86
Concession Fundraiser	\$800	\$0
Total	\$2,050	\$579.86

\$1,470.14 dollars were leftover after the ROV was built. The team was well under budget and this was done to make sure that in case something broke, there would be a surplus. The surplus is also going to be used as a startup fund for next year's team in the event where not enough money is made from fundraising to afford any supplies needed and to help cover travel expenses, until more fundraising can cover the cost.

Design Rationale

Frame

This year, Katana's frame was constructed from PVC pipe, PVC fittings and aluminum. PVC and fittings were used because of their stability. It was also one of the resources available. The frame is in a box shape, which helps keep the robot stable and sturdy. This simplistic design also allows for modifications to help with mounting; whereas a complex design would limit positioning of tools and cameras. Aluminum brackets were added to the frame to allow cameras and other tools to be attached more efficiently.

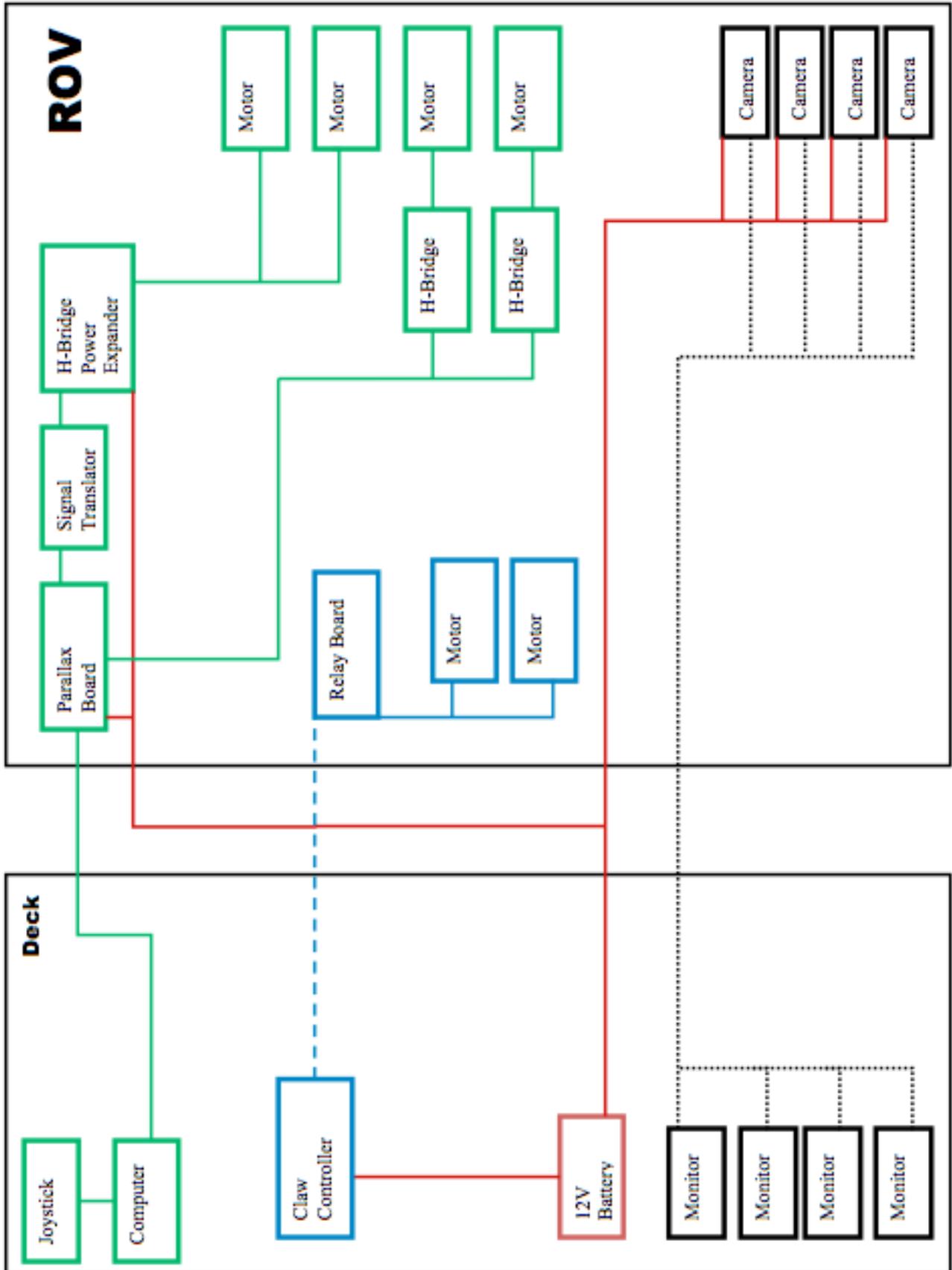
Cameras

There are four cameras on Katana, one each for the vacuum, the claw, general direction, and also for the magnets. The cameras are mounted in one-inch PVC couplings and have a plexiglass window eco-bonded to one end. The other end has a one-inch (diameter) PVC pipe, which varies in length for each camera. A one-inch PVC cap is put on the other end of the PVC pipe and had a hole drilled into the end to allow the wires to enter/leave the housing. The front camera is mounted using an aluminum bracket, bolted into the top of Katana.

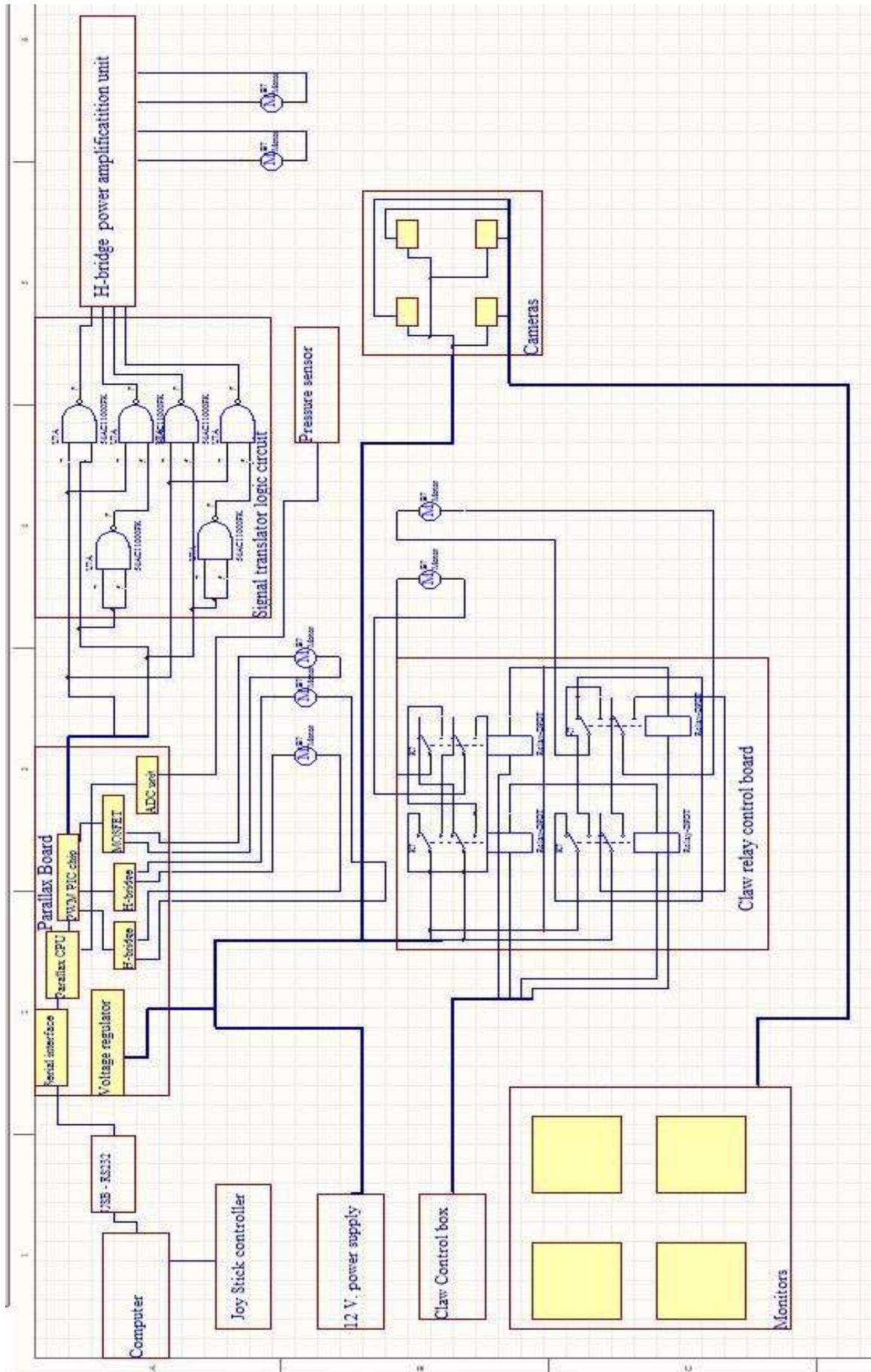
For the other three cameras, a pinhole camera is used. The vacuum camera is attached to an angled aluminum bracket, which is placed between the aluminum box and the PVC in the back of the ROV. The aluminum pieces that make up the bracket are riveted together which creates a slight bump, the distance between the PVC pipe and end caps, allows for the housing to be secured tightly. To help secure the bracket, JB Weld was used between the PVC pipe and the aluminum bracket. A camera for the magnets was mounted in a similar way as the vacuum camera; except for it extends further into the ROV. The last camera is mounted inside of the aluminum box, which houses the electronics and "brains" of the ROV, which will be discussed later. The camera is on an angled piece of aluminum, which was JV Welded to the inside, top part of the box. The plexiglass window is clear and the angle, which the camera is at, makes it possible to see the claw and its movements. An aluminum bracket keeps the camera at that set angle and position in the box.

A problem experienced with cameras in the past was their dying out from the constant expanding and collapsing of a magnetic field the motors created as they are activated/deactivated. This was fixed by integrating a capacitor into each individual camera's wiring.

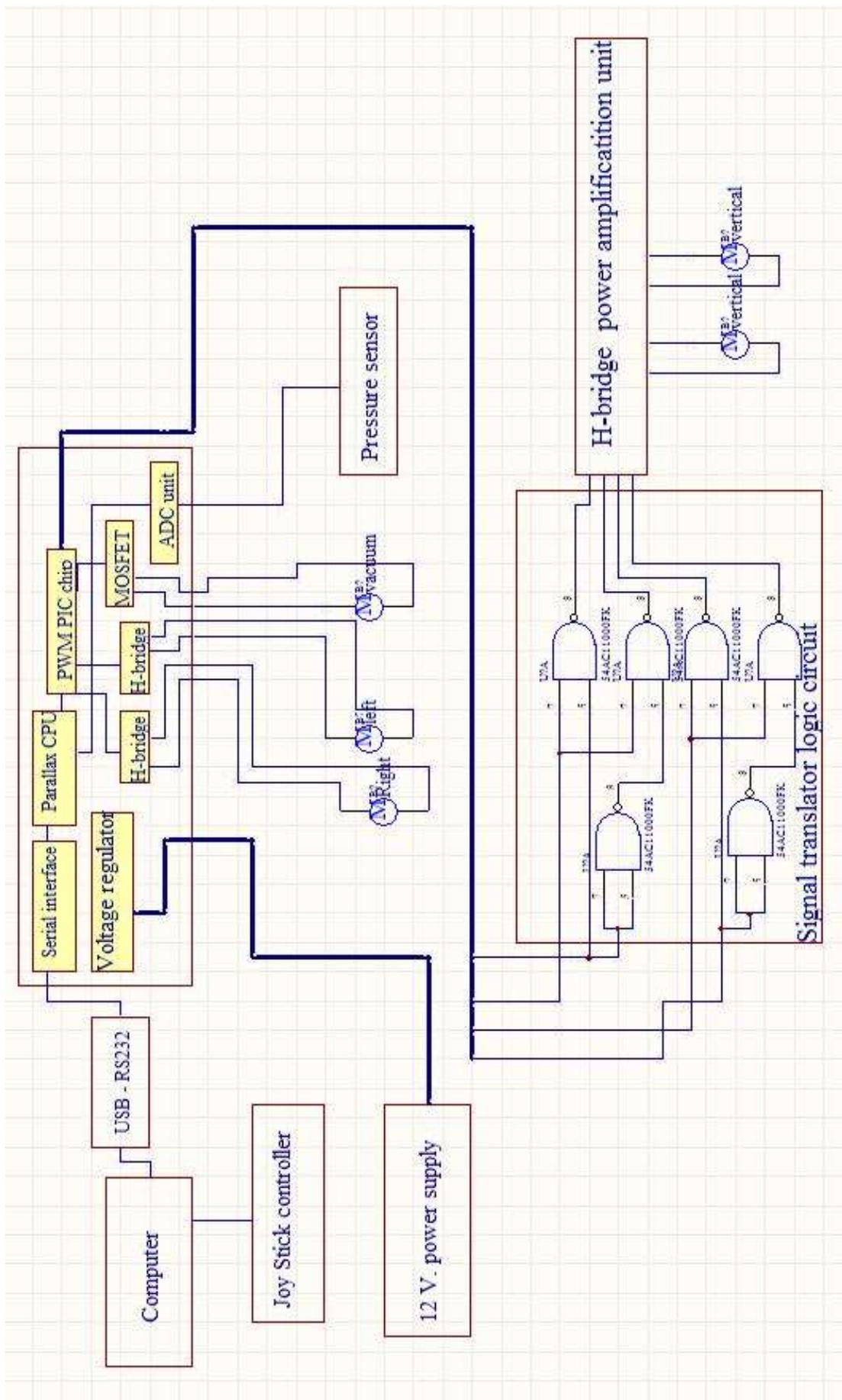
Block Diagram



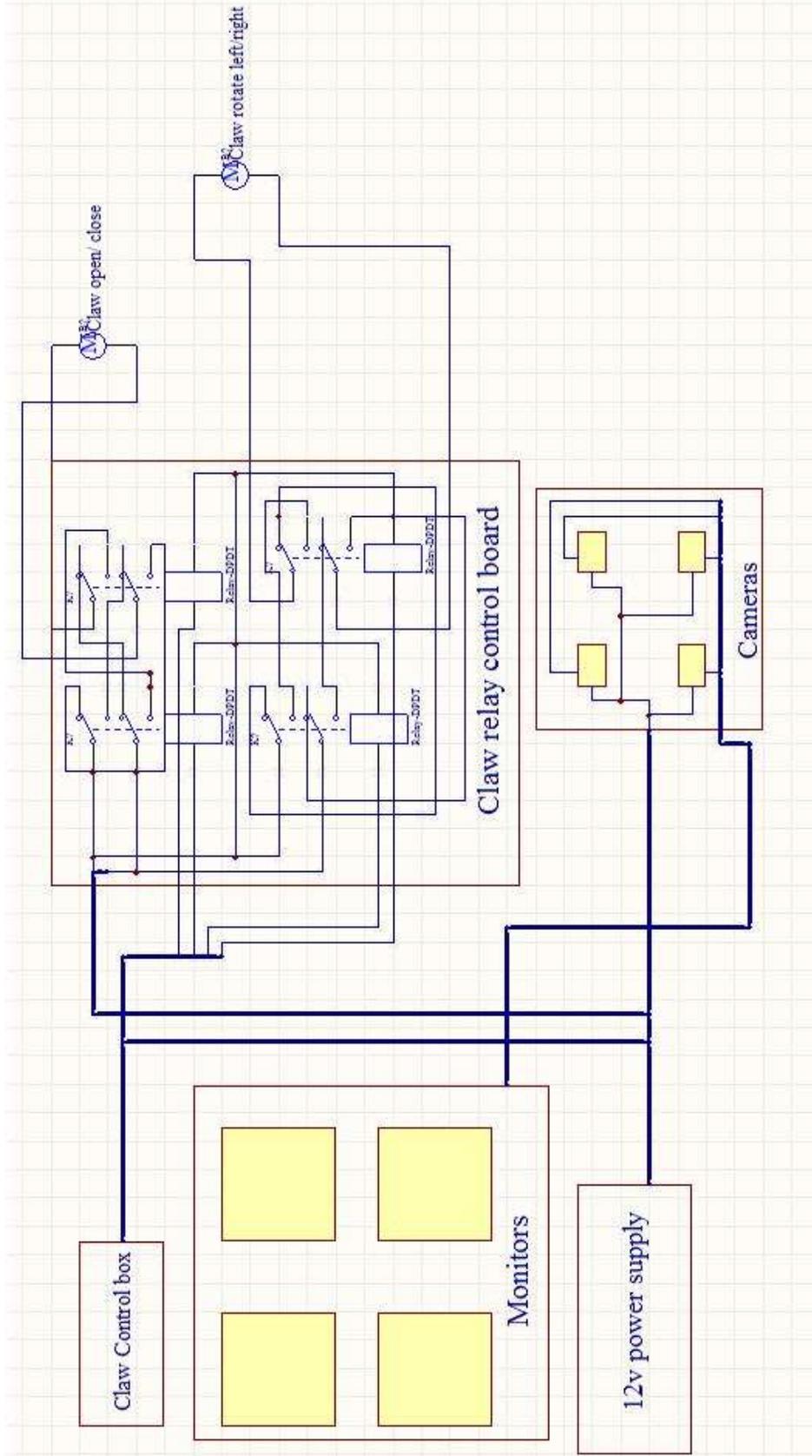
Electrical Schematic

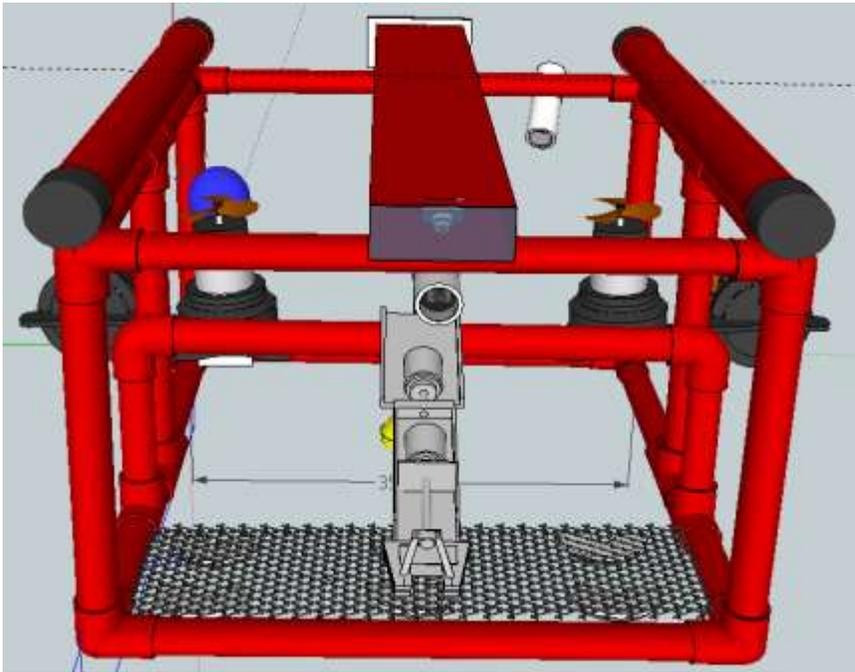


Parallax Board Motor Control System With Pressure Sensor

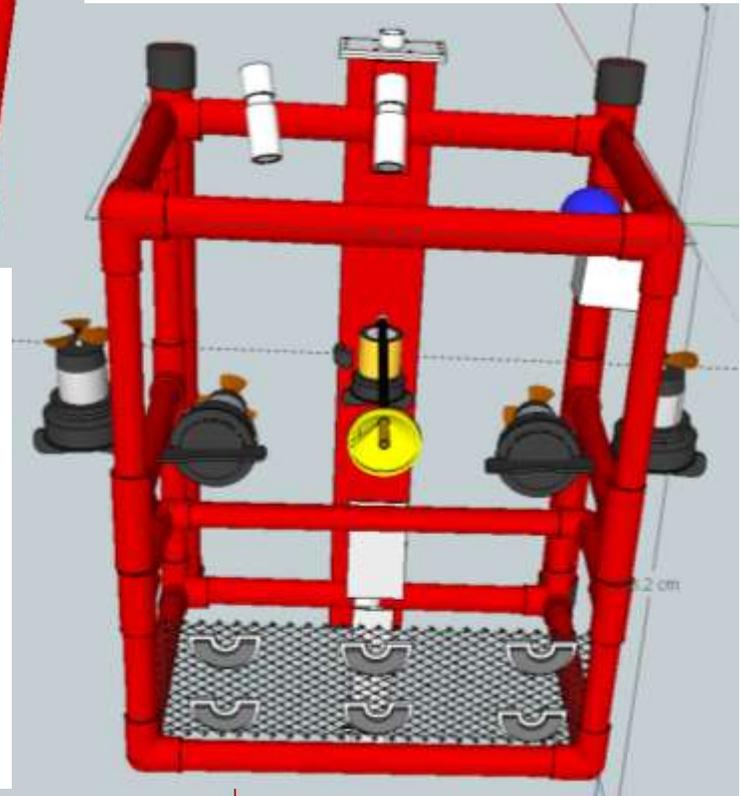


Claw Relay Control Box and Cameras

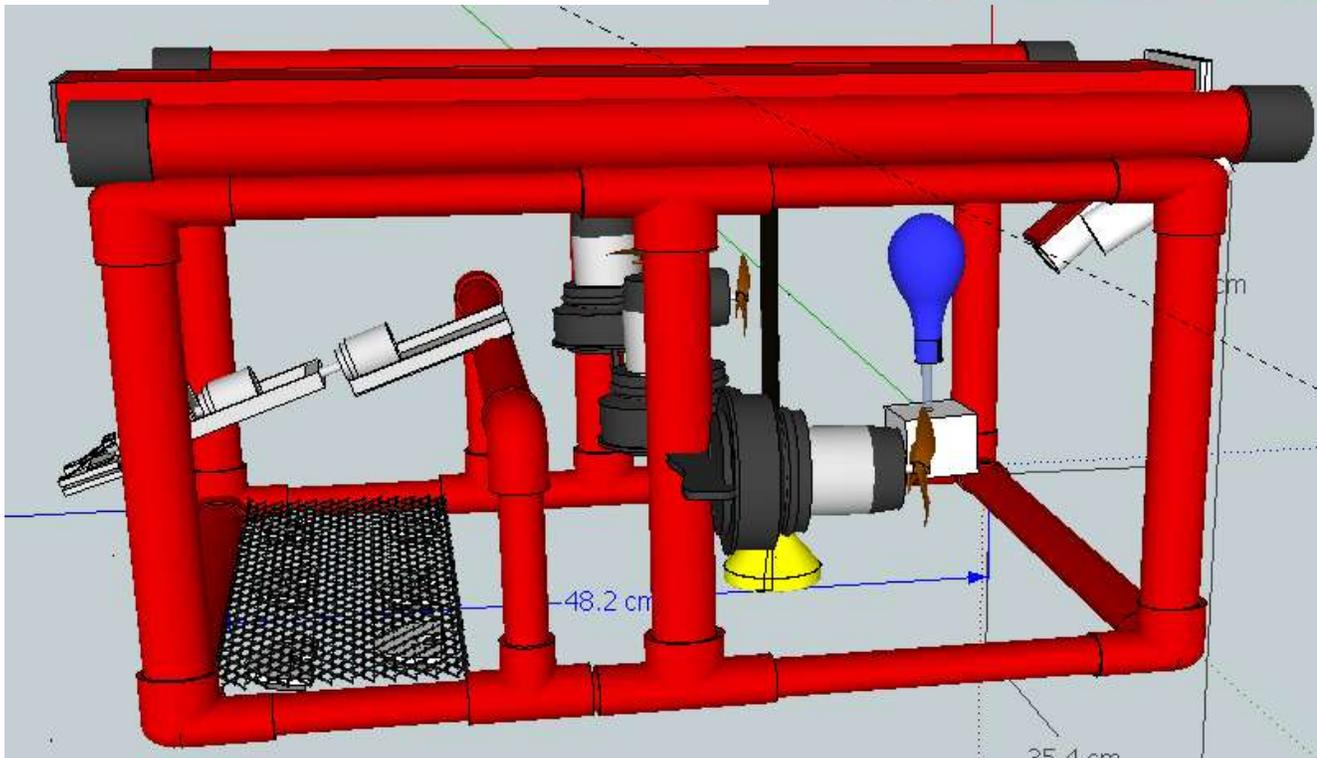




Left: Front View of Katana



Right: Bottom View of Katana
Below: Side View of Katana



Motors

Due to the depth that the ROV must reach, 1250 gallons per hour (GPH) motors were used for upward and downward propulsion. This allows the pilot to get the ROV down to the bottom and back to the surface as quickly as possible, also giving the pilot time to complete the missions. For left, right, forward and backward propulsion, 500 GPH motors were used because of the amps the Parallax board could handle. The 1250s required more amps; so new H-Bridges that could handle more than three amps were added (this will be further discussed in the electronics section). The 500s draw approximately three amps underwater, which is the maximum the board can handle. Using the 500s also allow for more precise movements for the more complicated tasks.

Shrouds

The shrouds are made out of chicken wire and placed around the motors and propellers, creating a basket shape. This is done as a safety precaution and as a way to prevent the tether and other lines from becoming tangled in the propellers.

Control Boxes

Two control boxes were used this year: one to control the claw, the other to move the ROV. The one used to control the claw was made out of a black plastic box with two double pull double throw switches. One of the switches is used to open and close the claw, while the other rotates the claw either clockwise or counterclockwise. The second control box is a gaming joystick controller, which controls all of the motors. This control box is connected to the laptop, while the claw control box gets hooked up directly to the tether.

Tether

The tether is composed of three Cat5 cables, four 16 gauge wires (two for power and two for ground), and a protective plastic casing. One of the Cat5's is used for the camera signal and power wires; the second Cat5 has wires for the claw's relay board and the signal wires for the laptop; and the third is a backup Cat5 in case any wires need to be replaced. Having four wires for power helps optimize the amount of voltage and current that is sent through the tether, with a minimal amount of voltage and current loss through the 60-foot tether.

“Water Proof” Box

The quotations indicate that the aluminum box that contains the brains of the ROV was not always waterproof. A clear piece of plexi-glass was used to seal one end. The piece was first eco-bonded to the aluminum and then covered with resistive thermal vulcanizer (RTV). On the other end, two plates were created to make a cap. Holes were drilled along the rim of both plates and tapped for snug fitting screws. The plate permanently attached to the box has a groove that was originally made for an o-ring, but then a gasket replaced the o-ring, and finally electrical putty was used as a substitute for the rubber gasket. This was done as a way of sealing the box with minimal force to prevent the other seals from breaking. A seal that could be affected was the one between the plate mentioned before and the aluminum box. Originally the two were connected with eco-bond and then covered with RTV, but there was still a slight leak. As a result, a marine adhesive was used for a sturdier and stronger seal between the two pieces.

The second plate had a hole drilled in it to allow the wires to enter and exit the aluminum box. Once the wires were placed through the hole, resin was used to prevent water from entering the box via that hole. These plates were machined using a mill and the parts of the plates that were not needed to make a seal were sandblasted. This helped smooth sharp edges and got rid of any marks left on the

metal, such as Sharpie marks or scratches. Another part of the plates that was sanded was the o-ring groove, except this was done by hand to prevent anything from becoming too deformed or damaged.

Heat Sink

A metal heat sink was attached to the Parallax board's components to help diffuse the heat that could cause them to overheat, fry or shut off. The metal block that is attached to one side of the box touches the inside of the aluminum box, which allows the heat to diffuse to the larger aluminum box and then to the water surrounding the box. On the other side a piece of rubber was used to help insulate the bare metal ends to prevent shorting anything out.

Tool Design

Claw

The claw consists of two planetary Faulhaber motors. Having two motors allows for an opening, closing, and rotating action. The rotation from the first motor allows the claw to grab anything that may be at an obscure angle and can also be used to rotate the valve. The claw is made out of aluminum, which makes it rust resistant and relatively light.

Hook

A hook was created to bring the rubber well cap down. This hook is also used as a backup tool in case the claw fails while completing the missions.

Grappling Hook

The grappling hook is a different hook from the one used to carry down the rubber cap. This hook is to be brought down with the claw and inserted into the hook at the u-bolt. A bracket was epoxied to the end of the hook, allowing it to be inserted into the claw. After the pipe is cut, and the broken pipe is brought up to the surface.

Hard Drive Magnets

These magnets are used to pick up the various sea creatures that are lying on the bottom of the pool. All of the creatures have a piece of magnetic metal in them, which allows the pilot to drive Katana over them and pick them up in a quick swipe.

Pressure Sensor

The pressure sensor is encased in room temperature vulcanizer (RTV) in a clear box, which allows the team to see if there is anything in the container that shouldn't be there. A thin piece of plastic tubing extends out of the box and is attached to a rubber bulb. The rubber bulb contracts under pressure which causes the air inside to increase the amount of pressure, allowing the sensor to tell the pilot that they are going deeper into the water. The bulb has a relatively large surface area, which helps detect slight changes in the pressure since there is more surface area that can be contracted.

Electronics

The relay board is an electromagnetic switch. A magnet, when triggered, will pull two poles in the switch from one contact to another, "relaying" and amplifying the signal. The team used relays to activate two motors on the claw. The board uses two relays per motor allowing the motor to drive in more than one direction. This is due to how the relays are wired. Relays were used to cut down on the

size of the tether wires. While during research, it was discovered that two 18 gauge wires per motor is the most effective at transferring current. This made the tether extremely heavy and this caused the ROV to become sluggish. The relays that we are using require very little current to trigger therefore the wire gauge needed to effectively transport this current was greatly reduced in turn reducing the weight of our tether and only four 18 gauge wires are needed for power.

Previously, relays were the primary control system, but this year, the team made the jump to using a Parallax control board. Some components of the control board include software programming and hardware integration. The Parallax board was a kit designed by MATE ROV competition coordinator Mr. Scott Fraser. While the board is the foundation, other components are needed. These components are: a computer to run the Parallax software, a Logitech game controller, and a 12-volt power supply. The power supply is fed into a voltage regulator, which filters out all the electronic interference and supplies voltage to everything on the board. The program in the computer communicates directly with the central processing unit (CPU) on the Parallax board via a universal serial bus (USB) to the serial cable RS232 interface. An USB cable can only carry signals 50 feet and as a result, an interface connector was used to convert the signals to be run down a RS232 cable. From the serial port on the board the signals are then processed in the Parallax CPU and sent to the programmable interrupt controller (PIC) chip micro controller. The PIC chip then sends signals to the H-bridges they are an electronic circuit which allows for power to be applied across a load or in this case a motor in either direction allowing for our motors to be run in both forward and reverse. The thruster that controlled our forward/backward/left/right movement ran off the H-bridges.

The vertical thrusters required much more current that the H-bridges supplied by the Parallax kit could manage. A H-bridge power amplification unit was purchased to replace the H-bridges designated for the vertical thrusters on the board. The function of this circuit is to simply boost the amount of amps put out without losing any of the precision post-width modulation control. How this circuit works is through electronic isolation the signals from the PIC chip are run through a series of integrated circuit (IC) on a separate board, which were “and” and “nand” gates which where used to translate the signal into a value the power amplification unit could read. The signals are then fed into another IC, which turns off and on light emitting diodes (LED). The LED’s are encased in plastic so they only communicate to the photovoltaic sensor in the same encasing, which electronically isolates the components. The signals from the photovoltaic then activate a p-type (PNP) or n-type emitter (NPN) transistors, which distribute the power to the appropriate vertical thruster motor. The vacuum device is run by the metal–oxide–semiconductor field-effect transistor (MOSFET), acting like a relay only in a solid-state which means no moving parts. The MOSFETs are activated by the PIC but current can only flow in one direction.

Programming

The ROV board controls both the movement and the sensors of Katana. The programming section of Katana is composed of multiple parts: the BASIC Stamp, the PIC chip and a laptop. The BASIC Stamp, otherwise known as Stamp, acts as a bridge between the sensors on the Parallax board, the PIC chip and StampPlot. StampPlot is a user interface used to display joystick and sensor values. The PIC chip is what controls the pulse with modification (PWM) signal and the direction of the motors based on information sent by the joystick.

When the joystick is moved, the Parallax BASIC program (PBASIC) tells StampPlot to verify position, display it on a meter and send it back to the stamp. The stamp then interprets and scales the data and sends it to the PIC chip, which will adjust the PWM signal accordingly.

The information from the pressure sensor is transmitted through the tether as analog voltage. From here, the information is sent to the analog to digital converter (ADC), where it is converted into digital data and kept available for the stamp to read it. After reading the ADC, the information is scaled to centimeters and sent to StampPlot to be displayed on a meter.

Pins, which are physical contacts that the stamp can interface with, are where the software meets the hardware. For example pin 1 will connect to the PIC chip, pin 7 to an LED and so on.

The program then sets aside certain blocks of memory have corresponding functions. These are known as variables and are given names that correspond to what type of information they store. For example, potX is used to name the value of the x-axis of the controller.

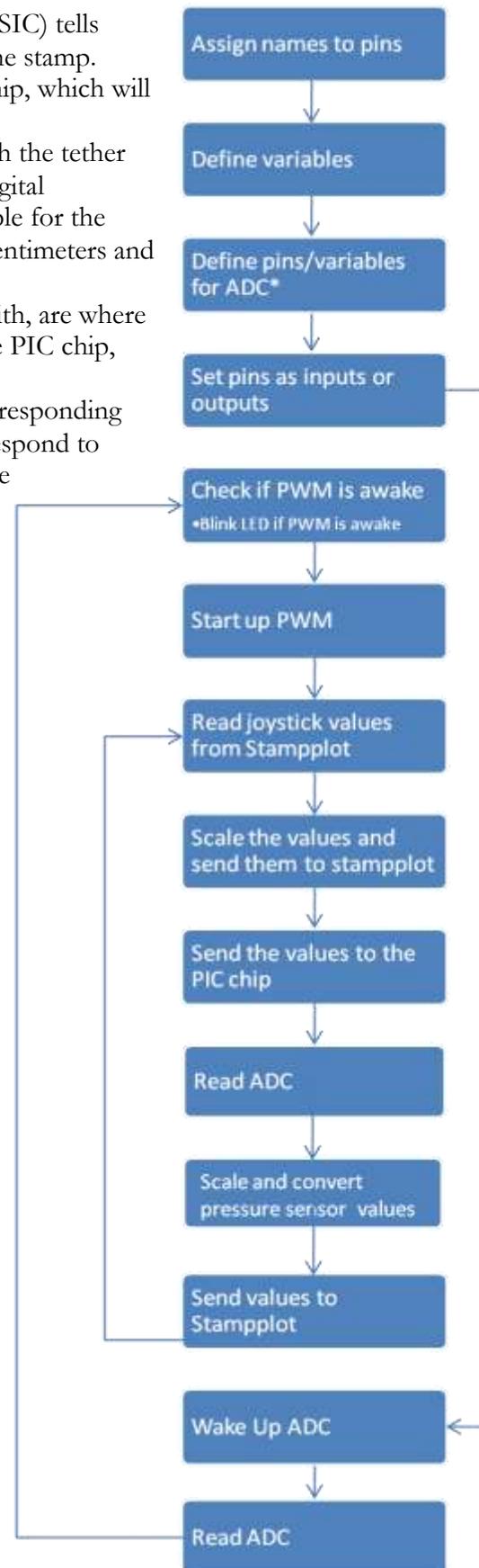
Defined pins are set to either send or receive data. The program then wakes the ADC up with a dummy command, which reads and stores any data that has been gathered by the program. LED 8 can verify the status of the PWM, if it is flashing.

When Stamp begins to read the joystick values, the first LED is toggled on and off to indicate that the program is cycling. The range of the joystick values run from 0-65535, while the PIC chip can only read from 0-255. Consequently, dividing the joystick values by 256 scales the joystick values down, allowing the PIC chip to understand it.

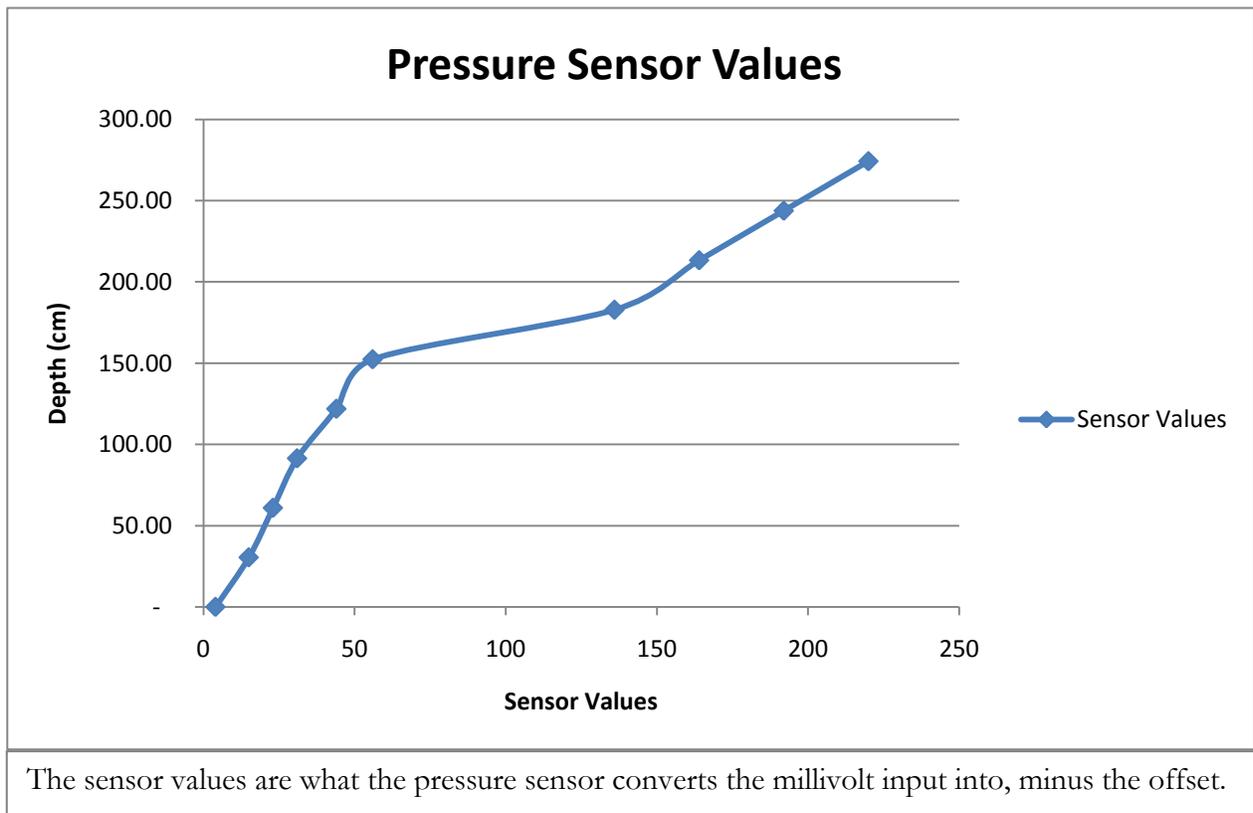
The up and down movements are read as values from 1-3 with one being idle, two being up and three being down. The two buttons that control up and down have values ranging between one and zero, so if they are taken as-is there is no way to differentiate between up and down. This is why the equation $potV = 1 + datain(0) + (2 * datain(1))$ is used, with potV being the value of the vertical thruster, datain(0) up and datain(1) down.

The values are then sent to the PIC chip. Here the x and y values are integrated into PWM signals. This allows the motors to be controlled by one joystick.

The program then starts reading the pressure sensor value. Its value is then set to start at 0 (by subtracting a value to offset it), and the equations to scale the sensor to centimeters are applied. The reason for multiple equations is because the sensor jumps when the depth gets to 5 feet, then starts leveling out again (fig. x). We separated the graph into two different equations by using a SELECT...CASE routine that uses a different equation based on what value is received, ensuring the sensor stays accurate. The stamp then sends the values to Stampplot and goes back to the joystick control section. The program then loops back and forth between these until the board is turned off.



*ADC = Analog to Digital Converter



Challenges

One challenge that the team had to overcome this year was to learn a new system. Learning to read and write code, constructing a Parallax board, and understanding the relationship between the board and code. For the new electronics and programming to be understood, a lot of time was spent on those two components alone. Without the code or board functioning, tools and motors couldn't be tested. Through trial and error, certain problems could be identified in the code and fixed.

Another challenge that the team experienced, included meeting dates and times. Many team members had conflicting schedules, meaning there were few meetings where every team member would be present. As a result of this, two meeting dates were devised so if someone couldn't make one meeting, then they could make the other meeting. Also, to improve meeting productivity, since not everyone would be available to work, to-do lists were created. The lists were specific for each person that would present at the meeting and changed every meeting.

Troubleshooting Techniques

One problem that arose during the physical construction of the ROV included waterproofing the electronics housing and cameras. Multiple different products were used in an attempt to keep the box waterproof, including eco-bond epoxy, RTV sealant, and a marine adhesive. The construction of the claw also took a lot of time and had a few design flaws that required it to be modified. Remaking a majority of the claw and allowing for a few changes in how it works addressed this issue.

A problem that couldn't be controlled by the team, included when parts would arrive. The availability of parts is slightly limited because not everything was available locally and needed to be ordered from elsewhere. With the team being based in Hawaii, shipping days and times are not always consistent, especially since some of the sites had never been ordered from before. To make sure that

parts were received in time, they were ordered with a couple leeway days in mind, in the event that the parts take longer to come in than expected.

Whenever a component isn't working properly the team has a contingency plan to help determine where the problem is. If the motors are not working, the first thing that is checked is the board inside the box on the ROV; to make sure that the status lights are on. If they are, the second thing to check is whether the software is responding. If the software is working, then the connectors that carry the board signals and main power will be checked. If the problem still cannot be identified, the multimeter will be brought out to test all connections to determine where power or signals are lost.

If the monitors are black or if there is no signal, the connectors are all checked to make sure that everything is connected properly. If the monitor screens are black, that means that power is being lost somewhere. If the connections are fine, then the multimeter is brought out to test connections. If the monitors have power but read "no signal," then the signal wires are followed and connections tested with the multimeter. If all connections are good and everything is receiving their respective signals, then the cameras have died.

Future Improvements

Some things that needed to be improved on include updating and following the items posted on the teams website, to help run meetings more smoothly. At the beginning of the work schedule, to-do lists were not specific, meaning that tasks weren't assigned to any specific person. Eventually tasks were given to each individual. In the future, to further improve scheduling, times will be allotted to each task.

Posting checklists and schedules on the room walls would allow everyone to see what needs to get done at a glance and notes could be made next to each task. This would improve the efficiency of the meetings, would prevent having to login to the computer and search for the email with the day's list of things to do. Other things that would be improved include cleaning up the work area throughout the meeting so everything can be found when needed.

Reflections

Quintin: Some things just never change, the constant struggle against leaks, mechanical errors, and many trips back to the drawing board. However, some things do change. For example, a new type of control system was used, including actual programming and a large extravagant controller board. This year I had the privilege of putting together the hardware in our control system and designing and fabricating several different tools (the vacuum device and the claw). I believe that this year was a season of rebuilding and development. As a team we took a large step in the advancement in electronics to gain more precise driving. This was a whole new learning experience in and of itself. New sets of skills are needed to build circuit boards such as the technique used to solder surface-mount components. Also having members on the team that were totally new to the ROV program was a slight challenge. However this was a very good challenge because it forced me as a veteran ROV to examine my knowledge from previous years and sometimes relearn things because I had to teach others. All these things added up to another great ROV season and inspired me to further pursue a career as a mechanical engineer.

Taylor: This was a very fun and interesting experience for me and I learned a lot. This being my first year in ROV one of the things I found challenging is figuring out what my more experienced team members were telling me to do. I learned how to solder which is very important to life, like if I ever

need to miciver something, then I can. What I liked most about ROV is meeting new people and making friends.

Kellie: I learned and gained many skills in my first year of ROV. Some lessons include working with peers and people in the community, mechanics of electrical work, and how to time manage. I never knew how much time and effort was put into completing a working robot. From start to finish is an amazing thing that has brought me much application for all electrical components are everyday electronics such as the microwave, cars, and televisions.

From the first day I signed up there has only been positive experiences that are helping me learn and grow. There were obstacles that as a team we had to overcome such as people not showing up all the time but we adapted and found alternative things they could do. Also I did not have much experience with wire works and got a taste of how currents work with help from the more experienced members of the team. We all must problem solve which is an important skill to have and can be applied outside of the ROV season. For example where to get supplies, and how are the materials going to be used without wasting. ROV has given me many positive skills, and fond memories that will last a lifetime.

Max: This R.O.V season taught some very valuable skills, such as computer programming in P-BASIC, how to build a simple circuit board, and the most effective way to attach objects to the R.O.V. Some challenges that I had to overcome were a conflicting schedule, and a programming misinterpretation. A skill I gained was time management. Some things that I enjoyed were over coming challenges, using limited resources to solve problems, and being able to see ideas take shape.

Vernon: Ever since the beginning of ROV, I have been finding new ways of completing tasks, such as how to remove solder from a component. I learned how to put together a propeller efficiently and place it on as such. I learned how to solder a circuit board, use different solder tips and various other expertises. I enjoyed working in the shop we had. Both of our instructors were very helpful in getting what needed to be done. In addition, I do not recall a single argument between our groups and could say that our team had great overall teamwork. Each team member specialized in something, such as programming, electronics, etc. The skills I gained overall were becoming more coordinated in driving, more accurate in soldering, and considerably experienced with Google Sketchup. One thing that all of us learned was to do something right the first time, that way we'll less likely have trouble in the future.

Erica: Every year you hope things will get easier, that with more experience and more practice, certain tasks will become second nature. We all forget the small things such as putting the heat shrink on before soldering the connection every now and then, but this year so many problems occurred, that you wonder what else can go wrong? Wanting a challenge this year pushed our expertise and knowledge out of our comfort zone and I believe that we came out a stronger team because of it. Despite the challenges and issues that needed to be overcome this year, we worked through them as a team consulting each other and reaching out for help when needed. The boundary between what can work and what couldn't, had usually been clearly defined in the past because we all knew what the limits of the parts we had were. This year, we reached out and tried new techniques and parts, which allowed us to try new things with the sky as the limit.

Matt: This year has definitely been a challenge for me, especially compared to previous years. The decision to integrate the ROV controller board was a challenging one, forcing me to learn a programming language and understand a piece of code. I learned that how important the little details are, especially in coding. One line or one number can be the difference between a working ROV, and a

broken one. The hardest part though, was putting all the software and hardware together into a working ROV (that's waterproof). It was a difficult task, but the experience was definitely worth it.

Team Work

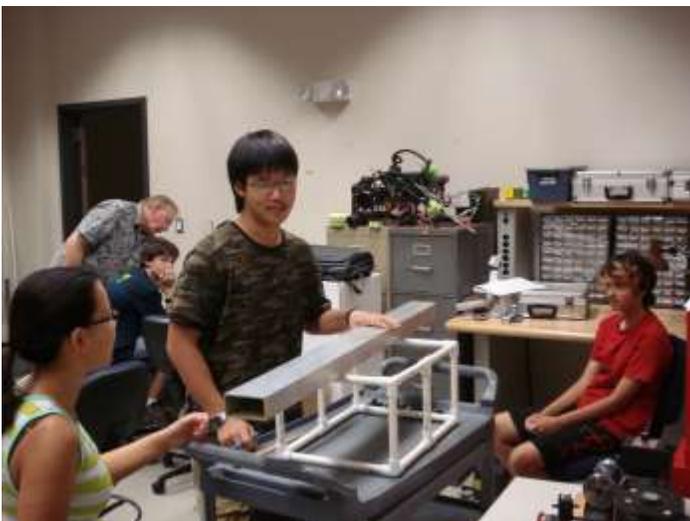
To ensure that all of the tools were built, a general timeline was set up via the team's website. Some due dates were pushed back due to complications that arose while making the ROV. Team members were assigned certain tasks to make sure that everything got done and everyone made it their responsibility to make sure that the tasks were completed.



From left to right: Matt, Quintin, Kellie, and Erica after first layer of o-ring groove was cut.



From left to right: Quintin, Taylor, Matt (hiding), Mr. Koenig, Erica, Taylor testing pressure sensor in 9 ft tube of water



From left to right: Erica, Quintin, and Taylor working on Katana prototype
In back: Max and Mr. Koenig working on Parallax board

Acknowledgments

We would like to thank our advisors, mentors, parents, sponsors and all other supporters of the company Hawaii 808 Ninjas.

Alumside



Central Supply



MATE
MARINE
ADVANCED
TECHNOLOGY
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Hawaii Electric Light Company
Giving you the power



Hilo High School

