漢基國際學校
Chinese International School

Underwater Inc.
Hong Kong 2011 MATE ROV Regional Competition
Ranger Class

Technical Report

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Abstract

The 2011 Marine Advanced Technology Education (MATE) ROV competition revolves around the recent disaster at the Deepwater Horizon drilling rig explosion, repairing the damaged oil well and the collecting surrounding biological and chemical samples for further scientific investigation.

The 力^{3} ROV is the team's attempt at instilling in younger, middle school children an interest in the cutting edge of science and technology. An adaptation of the 2010 力^{2} ROV, this year's version is the culmination of a three-month training robotics training programme aimed at middle school students and a further two-month's worth of investigating, designing, planning and actual engineering.

While the result of the five months of work was a robot that is impressive in itself and fully prepared for the challenges posed by the competition, this year's objective for the 力^{3} ROV was different. Rather than making of the most capable underwater robot around, this year's aim instead put an emphasis on those of the MATE Centre's – giving the future generations a scientific and engineering education that the 力^{3} ROV team believes to be invaluable in today's society.

The following is the 力^{3} team's technical report of their eponymous ROV, 力^{3}. Within this report are detailed descriptions and illustrations of 力^{3}'s main components (including a detailed expense budget, electrical schematics and software flow-charts), troubleshooting information, challenges met and their respective solutions/lessons, possible future improvements, and information on the recent Deepwater Horizon oil spill.

Vehicle Systems

Adapting from the 力^{2} ROV, the team's focus with this year's 力^{3} ROV was a further extension of the modular design into a platform for designed for educational use. Simple and robust, the 力^{3} ROV's modular system easily accommodates additions and possible refits, giving it a long-term edge that ensures its relevance in future competitions, hence allowing students to focus more on higher-level modifications rather than having to rebuild a new robot from scratch each year. Furthermore, the low costs of the robot thanks to original designs and work allowed the new team members to gain greater insight of various components of the robot. Moreover, this cost-efficient design makes it accessible to students of a diverse range of socio-economic backgrounds, allowing it to be adapted by others also seeking an engineering, scientific education.

One of the original features of the robot that complies with the cost-efficient, education-oriented design is the “brain” of the entire robot. Using a stripboard rather than a self-made circuit board, students will easily understand the basics of electronics, along with the electronics that the 力^{3} ROV will be operating with.

Another of these educational, cost-efficient features is the software being used by the pilots. Armed with a GUI (graphical user interface), piloting the robot has never been easier. Combined with an intuitive controller (a USB flight simulator joystick), students will find troubleshooting bugs in the robot's operation easy, not to mention making the piloting experience much more agreeable and enjoyable.

Materials used in the robot further extends its role as an educational tool. While materials that were most commonly used in the robot – aluminium, PVC and stainless steel – are relatively cheap, their ubiquitousness also makes the robot's design easily accessible by a whole divrerse range of students.

Given the students' relative inexperience, the aspect of safety in our ROV has never before been more seriously considered in the engineering process. Basic safety features like thruster housings, leakage sensors, fuses, and also some more complex features such as an internal temperature sensor for overheating detection, a digital multimeter to monitor the current flow, and more were incorporated into the robotics system.

Design Rationale – tasks

Aiming to provide a rich, scientific and engineering education for the students, it was necessary for the team to adapt a lot from the modular designs of last year's 力 ^{2} ROV, in order to ease the transition from simpler analog electronics into digital electronics. However, given the great difficulty of this year's objectives, the team has decided to place heavy emphasis on the planning and designing process prior to the manufacturing process. By doing so, we were able to create complicated systems in less time. We used CorelDraw and laser cutting processes to manufacture many different parts to ensure that there are no errors in the manufacturing of the parts.

The core of our engineering solutions for the competition challenges lay in our robot's ability to move, rotate certain objects, and also collect liquid samples. All of these tasks require a manipulator. So the team designed and manufactured a strong and robust waterproof claw (see Solidworks render below) that is capable of completing such tasks. The use of this simple robotic arm also complements the modular approach, with an emphasis on the interchange of different tools to solve problems.

Task #1 – Remove the damaged riser pipe

The first mission that the ROV will have to undertake requires that it makes use of a manipulator in order for it to remove the damaged riser pipe. To do this, the ROV's manipulator will be used to connect a line to the U-bolt of the damaged riser pipe to transport it to a “work area”. The line here is simply made from a rope with a flexible, aluminium hook designed with the U-bolt’s shape and size in mind. The next step would be removing a Velcro strip to simulate the cutting of the damaged portion of the pipe, and then finally moving this cut-off part from the work area. These last two steps will only require the manipulator.

Task #2 – Cap the oil well

This mission involves the re-insertion of a hose line from the top kill manifold into the port of the wellhead, the turning of a valve wheel to stop the oil flow, and then installing a cap onto the wellhead. The first and last parts of this task are relatively simple as they only require the use of the bare manipulator – the most difficult hurdles of these parts would lay in the piloting of the robot itself. However, the rotation of the valve wheel is complex enough that the manipulator itself is not enough to solve the problem. The ability to rotate the valve wheel itself, instead, comes from one of the robot's assortment of tools. Consisting of a motor and four prongs, the tool operates by rotating the four prongs, which then pushes the valve around three times, as required.

Task #3 – Collect water samples and measure depth

Two main components of the ROV are critical to the success of this mission – the depth sensor and a liquid-removal tool. Using a depth sensor installed under the electronics housing of the robot, the team will descend to the appropriate depth so that the right sample container will be easily chosen. At the nozzle of the sample container, the team will proceed to descend upon it with the liquid-removal tool, after which the liquid should be retrieved. The tool consists mainly of two tubes – a liquid storage tube at the side of the robot, and another that encloses a thinner tube that should bring the sample liquid up to the storage tube. With a conic plastic piece at the mouth of the liquid-removal tool, the nozzle of the liquid-removal tool is guided into the nozzle of the sample container. By pushing on the thin tube itself, the nozzle descends directly into the Platypus water bag, and a motor pushes a piston in the storage tube to bring water into it.

Task #4 – Collect biological samples

The final and ultimate task involves the collection of simulated biological organisms on the sea floor and bringing them back to the surface. By only driving certain motors, the team should be able to get the ROV to tilt at a certain angle for the manipulator to reach the sea floor, allowing it to grab any of the simulated samples and bringing it to the surface.

Design Rationale – ROV

Figure 1: The robot (without tools attached)

Frame

The The frame design used this year is an adaptation of last years', except that it uses a different configuration based on this year's changes to the electronics housing. With a predominant use of aluminium, the box-shaped frame is robust and yet light for improved mobility in the water, not to mention portability for testing purposes.

The frame easily fits eight thrusters in the current configuration, along with a complete array of tools, sensors and a manipulator. The use of aluminium makes the entire frame rust-resistant, extending its life as a suitable frame for underwater robots. It is also easily cut, reshaped and perforated, allowing future modifications to the robot simple to make. With bevelled edges, the frame itself is also very safe to handle.

Electronics

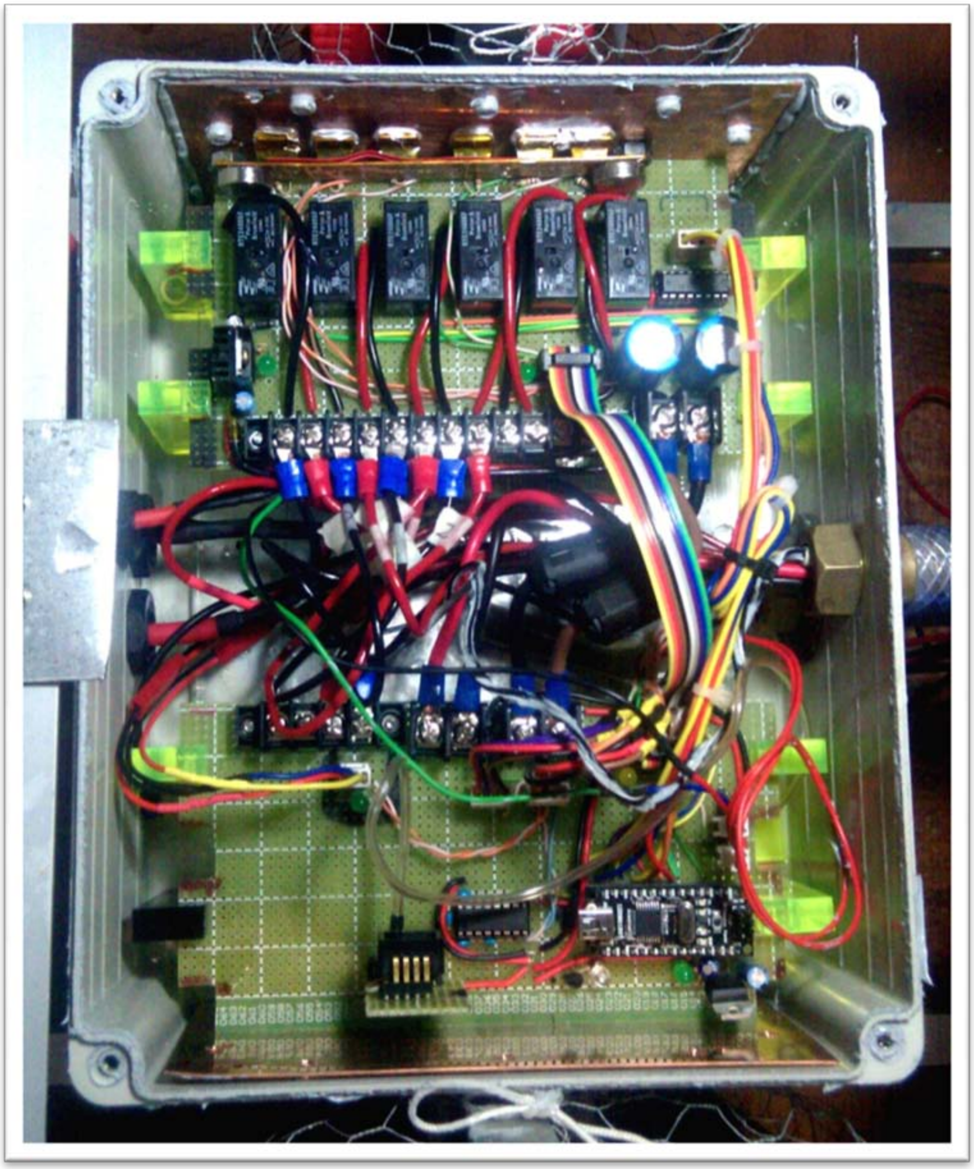


Figure 2: Inside the electronics housing

There are two main parts of the circuity in the ROV that makes it work – the control unit, and the motor controller.

All of the circuits are made by the team – to ensure everything was an original design, no commercial products were used, at all. To help train the younger students, it was decided this year that perfboards would be used instead of last year's circuit boards. Fortunately, this decision did not affect the overall originality of our robot.

The control unit is in charge of serial communications with the laptop above the water. It understands the commands sent by the laptop, and translates it into whatever it needs to do, for instance, open the manipulator, or send sensory information.It has a atmega168 microcontroller as its "brain", running AVR-C software, which is designed and written by the team. The MAX232 chip converts a 9600 baud serial signal from the tether into TTL signals.It utilizes mostly SMD components, with occasional DIP for important ICs such as the MAX232 and atmega168 for easy replacement and debugging. It features a hall effect current sensor and voltage divider connected to an ADC port on the AVR; a buzzer and LED for auditory and visual indication of activity, which is extremely useful for debugging; leak detection to inform the pilot when the enclosure has been breached, a 25A fuse to prevent dangerous short circuits; and capacitors to help smooth out the voltage fluctuations which prevents the AVR from resetting when there isn't enough power.

There are 6 pins of 1000hz PWM for controlling the motors, which are connected to the motor controller part of the perfboard. Another 3 pins are for controlling the shift register, which will be explained in a moment.

Figure 3: Relay and MOSFET combo

Figure 4: Arduino AVR uC

The motor controller, as its name suggests, is used to control the motors on the ROV. It is capable of controlling 6 motors.

To allow reverse movement, there are DPDT relays to form H-bridges. Each motor has an n-channel MOSFET, which switches PWM to control the voltage fed to the motor. A shift register connected to a ULN2003 darlington transistor array is used to switch the relays on and off. A shift register is used so only 3 pins are required (clock, data, latch) from the microcontroller, rather than wasting 6 pins.

Low Rds MOSFETS are used to reduce voltage drop across the MOSFET, which would heat up the component. There is a 1-wire temperature monitor located in the motor controller to measure ambient temperature, which will inform the pilot if the enclosure overheats.
The wire gauge used for the motors is 12AWG, which is suitable for 9.3amps power transmission – definitely enough.

Electronics Housings

Unlike 力 [2] ROV, 力 [3] ROV uses only one electronics housing. The electronics are housed in an inexpensive, PVC, IP-68 certified box, sealed with a rubber O-ring and secured with screws – a considerable improvement over last year's transparent lunch boxes.

Although our testing showed that the box was more than capable to handle pressures of over two metres under water for days, we were still not satisfied the box. One feature of last year's electronics housing that made it so suitable for testing and troubleshooting was its transparency. Being able to see around the PCBs allowed the team to easily point out problems with the electronics, which frequently occurred during our many tests. This year, the team cut off a large part of the lid of the box and replaced it with a clear piece of acrylic. To ensure the box's integrity, the acrylic was further secured with silicone sealant.

Figure 5: Copper plate water cooling

Another feature that we decided to put into this year's electronics housing that was missing from last year's version was an adequate cooling system. From past experiences, we found that our circuits frequently struggled with overheating issues, which we were still unable to fully solve at the international competition. This year we went for a water-cooling approach, that is, dissipating the heat generated by the circuitry into the surrounding water. This is done by cutting out one side of the PVC box and replacing it with a copper plate. On the inside, the MOSFETs, which were the most frequently overheated electronic components of the circuit, are directly connected to the metal plate. Other features of the box include several acrylic columns supporting the circuit board to raise the perfboard off the bottom of the enclosure, like raised houses. If the enclosure leaks, the water will enter from the bottom, activating the leak detector, but only actually affects the circuit boards when the water rises another 2.5 cm – providing the team ample time to rescue the ROV out of the water.

Figure 6: Acrylic lid

Propulsion System

The thrusters are 1100GPH bilge pumps. They are already waterproofed, which saves the team a lot of time. There are 8 thrusters, four providing vertical movement, and four providing horizontal movement – two on the left, two on the right. There are only 4 channels on the motor cotnroller to control thrusters, so each channel has two motors in parallel – the two on the left, two on the right, two in the front vertical, and two in the back vertical, all for twice the power. Each motor is fused with a 6A fuse, to prevent over current when stalled.

The propellers are fitted with three blades, and each blade has an approximate pitch of 15 degrees, and the blades are 3.5cm in diameter. A shroud is used to direct the water flow in one direction, providing optimal thrust.

Each motor requires 2.5 amps each at full throttle. 2.5*8 = 20amps (although voltage drop over tether hasn't been considered).

Safety

Due to the emphasis the 力 ^{3} ROV project puts on education, the safety aspect of the robot has been given unprecedented attention. The ROV has many safety features to protect both the ROV and its environment from harm. Fuses are incorporated to protect the electronics from getting damaged, as well as dangers to living organisms, humans and other animal species alike. There are nets on the thrusters to protect the propellers, as well as to protect any curious hands or divers in the swimming pool. There are also leak detectors to ensure no water will damage the circuitry.
Many other aspects of the robot have been designed with safety in mind, such as the water-cooling system and the frame.

Camera

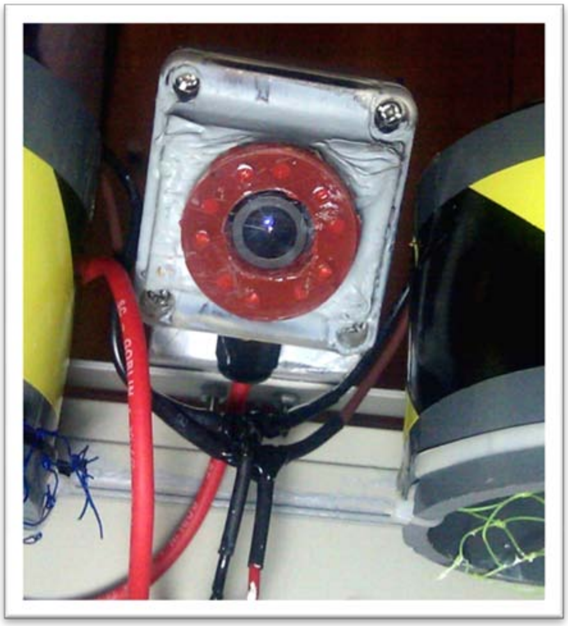


Figure 7: Waterproofed camera

The camera is a CCD color camera that works under very low light. The rear of the enclosure is waterproofed with a IP-68 certified PVC box, and the other half (with the lens) is enclosed by a clear piece of acrylic, sealed with silicone sealant. This design is not only water-proof, but has also proven to be extremely robust and solid. This is ideal for harsh underwater environments, and is sure to prove its worth in a relatively tranquil pool.

The camera enclosure is also long-lasting as its design makes it possible for future changes of the camera itself, in case it malfunctions or goes out of date. The enclosure has been tested to be waterproof at 5m depth for 24 hours, but is expected to be waterproof at over 20m deep.

Tether

The tether is 3 cables in a braid – +12v (red), ground (black), and an extra flexible cat5 cable (8 connectors). It is 15 meters long. It is extremely light and flexible, giving the robot less drag and more freedom.

The 8 conductors in the cat5 cable are stranded copper conductors, not the typical solid conductors, which makes it extra flexible. One twisted pair is used for the camera so the signal is always coupled with the ground, which allows for less interference and a cleaner video.

The power cables are 10awg, fully capable of transmitting 25amps bursts. Furthermore, a thick copper cable has less resistance, which allows for the lowest voltage drop while remaining flexible.

The conductors are braided for extra flexibility, and also to eliminate the use of cable ties or other methods of bundling – which is more elegant and simplistic. Since the tether is extremely light, neutral buoyancy was achieved by evenly spacing out intervals of floatation (not pictured). Neutral buoyancy is required to reduce drag.

Sensory

Other than the visual sensor (the CCD camera), another sensor has been incorporated into the robot to ensure its ability to complete the competition missions properly.

To complete task #3, the team has to be able to allow the robot to descend to an appropriate depth to collect a water sample from a certain container. Doing this requires a some sort of pressure sensor, which has been incorporated into the robot. Under the electronics housing, the pressure sensor is a Honeywell ASDX030, which offers a pressure range of 0-207kpa (0-30psi) and a burst pressure of 414kpa (60psi). Scuba divers generally acknowledge that a depth of one meter of water is an increase of one decibar, or exactly 10kpa – assuming this is true, the pressure sensor should be strong enough to be used in depths of up to 40 metres. The accuracy of the depth sensor has also been tested to the nearest centimeter – something that would prove to be very useful for task #3.

Other sensors include voltage, current, and internal temperature, providing the pilot with more information about the system.

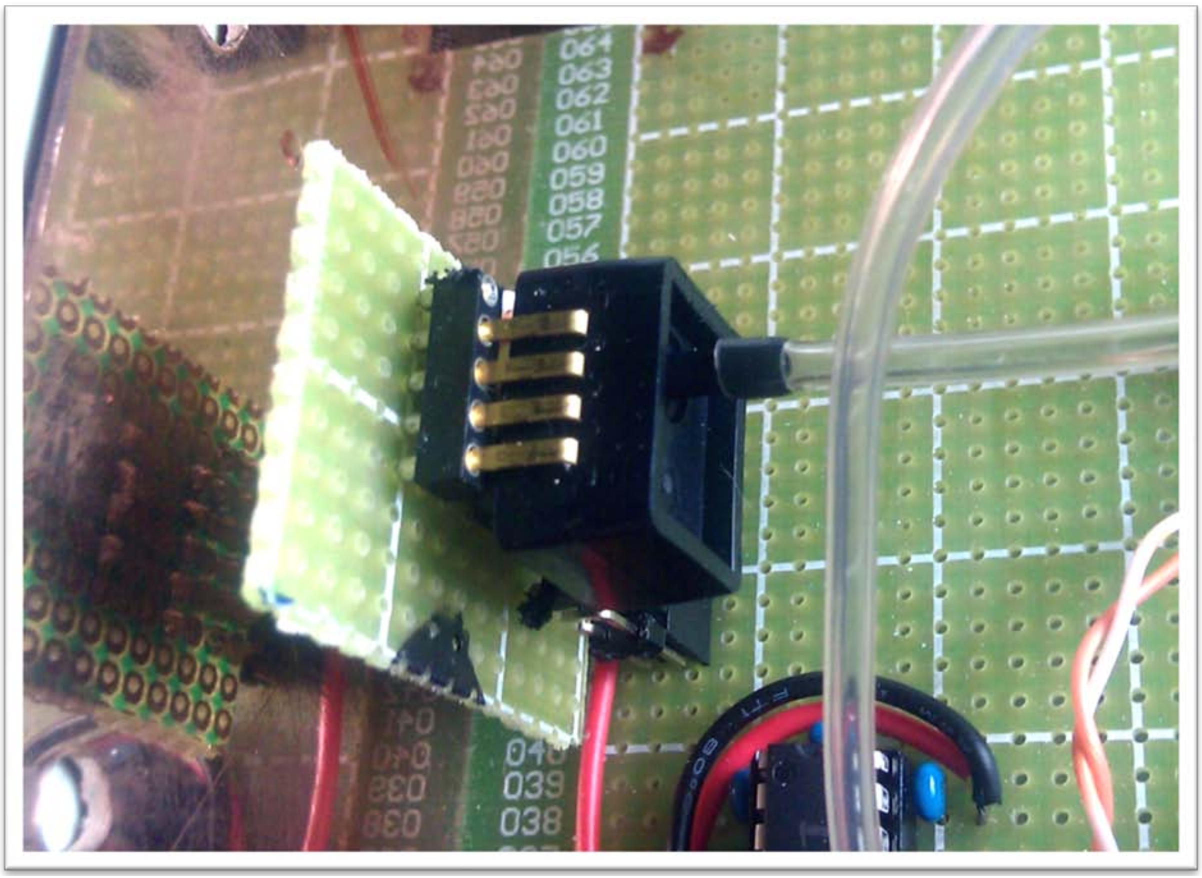


Figure 8: Honeywell pressure sensor

Surface control

On the surface, there is a USB ↔ serial dongle for communications with the ROV. There are also analog current and voltage meters (pictured below). Instead of relying on the onboard digital voltage and current meters as described above, these analog meters are here so that, just in case the serial communication doesn't work, it is still possible to figure out if anything is wrong, and hopefully also point out the source of the problem.

There is one 25A fuse to protect the entire setup. There is also a reset switch that is directly connected to the reset pin on the microcontroller, used to reset it if something is to go wrong.

Two power switches are also located at the control panel, used to switch the entire system on and off. We decided to use two instead of just one power switch as last year's switch proved to be not enough to handle the power (it eventually melted on the inside after hours of use). Using two power switches alleviates the stress on both switches, ensuring that malfunctions such as the one that happened last year will not happen.

Furthermore, a USB flight simulator joystick is connected to the laptop to control the ROV directly.

Figure 9: Topside "blue box"

Please note that it is extremely dangerous to connect the power cables in the wrong way. Capacitors will blow up and chips will get fried.

Software

There are two pieces of source code in this ROV – **topside** and **onboard.**
The **topside** software is written in Object Oriented Java, and coded in the NetBeans IDE. It features a GUI, which displays information about the sensors, the thrusters, and the joystick. It uses a joystick to control the ROV.

The software is heavily based on threads. There are in total 3 main threads – First, **the joystick thread**, which monitors joystick activity, and updates the joystick information. Second, **the serial-write thread**, which checks the joystick information every 10ms, to see if anything has changed. If there is change, it will send the data as thruster speeds to the ROV. This needs an additional thread to avoid the congestion of serial data. Third, **the serial-read thread**, which is in charge of parsing serial data that has been received from the ROV and displaying the data on the GUI.

There is a mode pre-launch checklist mode/diagnostic mode, where the pilot is required to execute before the launching the ROV. It checks the motion of the thrusters (direction and speed), and checks the validity of the sensory information. Once these checks are satisfied, the pilot can continue with the operation.

The joystick used is a USB flight simulator joystick, very accurate and precise, perfect for controlling a vehicle that needs precision for its missions.

The other part is the onboard program–code on the AVR microcontroller. This piece of software is significantly less complex. It is in charge of listening to the topside serial communications, and acting accordingly. When the Java program says “turn thruster 1 on”, the AVR microcontroller will turn thruster #1 on.

Every 500ms, the AVR microcontroller will read all the ADC and 1-wire values, and send all the sensory information to the Java program.

Throughout all the serial communications, a pearson hash is used for every transfer to insure error-free data transfer. CRC could have been used, but when data is being transmitted every 10ms, CRC would be too slow.

All software is entirely coded by the students in the team; the only code that was used that was not coded by the students are the libraries that controls serial communications: RXTX, and joystick input: JINPUT.

Manipulator and Accessories

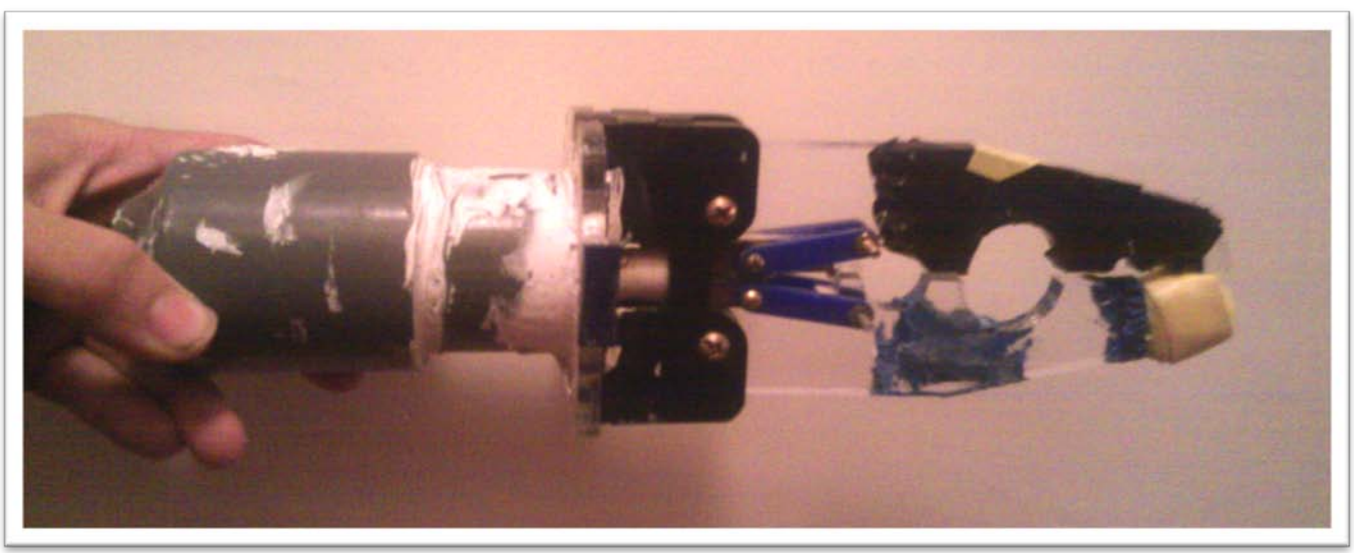


Figure 10: Laser cut arm

The manipulator is laser cut, consists of mostly 3mm, 6mm, and 9 mm acrylic, some PVC plastic, and a high torque gear motor.

The liquid-removal tool consists of a bilge-pump motor, which operates a piston enclosed in a silicone and epoxy-sealed acrylic tube. This tube is connected to another thin acrylic tube via a bendable rubber hose that is meant to retrieve the liquid (as directed). Guiding this thin nozzle is yet another acrylic tube, of the same width as the storage-tube, which encloses a spring and sports a conic opening at the “business-end” (where it touches the sample container in the pool) so that inserting the tube underwater correctly into the water sample is hassle-free task.

Another of the manipulator's accessories is the valve-rotator. Connected to a bilge-pump motor is a cross-shaped piece of acrylic and four PVC prongs. All of this is held together with a handle, which will be the place at which the manipulator itself holds onto.

Future Improvements

One huge annoyance and problem we had this year was the lack of proper electrical connectors. The current connections are complicated and time consuming. If we had bought waterproof connectors, instead of creating them ourselves, troubleshooting would have been much easier as it would have been much easier to remove the circuit boards from the enclosure.

Another improvement we could have done is to have thicker power lines in the tether. Even though this would increase the weight and decrease the flexibility of the tether, there would be less voltage drop across the tether, allowing more power for the thrusters.

Another improvement we could make is to add multiple cameras. During testing, we discovered that one camera was not enough to confidently complete the missions. However, there wasn't enough time to manufacture another camera before the competition, and we did not leave extra conductors in the CAT5 cable for another camera signal anyway.

Troubleshooting

With every engineering project, it is natural, almost inevitable that there will be difficulties and problems that come with it. This is not a fault of the design; it has been said that the difference between a good engineer and a bad engineer is the number of mistakes he makes. Regardless of the amount of time put into the designing and preparation of a project, there is always a problem, and over the years of attending the MATE ROV competitions, our team is well aware of the importance in troubleshooting and the skills that accompany it.

Trial and error has time and again proved to be the simplest technique of troubleshooting. Although generally tedious – trial and error consists of identifying an isolating a problem, brainstorming and testing possible solutions and then using one of these solutions – it nearly always produces the surest results. A relatively basic problem we had was achieving neutral buoyancy. When the 力 ^{3} ROV was put into the water for the first time, it was tilted at an angle due to an imbalance of the ballasting forces of the robot. To counteract this, we tried to find out where and what the source of the problem was by isolating different parts of the robot and seeing which seemed to be providing the greatest imbalance – in this case, it was the floatation device itself. We then proceeded to experiment with different solutions, such as using different materials and repositioning the actual floatation device. In the end, we decided to reshape the actual floatation device itself, cutting it bit-by-bit to see if it achieved the right balance.

While different, troubleshooting the electronics is somewhat similar. We found that a general use of online schematics and datasheets, signal tracing with an oscilloscope and voltage and continuity testing with a multimeter was really all it took to solve most of the electronics problems. One of our major problems was with the camera – because the camera is connected to the 12 volt power that comes from the tether rather than a battery, when the ROV was put into the water and ran, the camera would frequently turn into a black screen when the motors are operating. After observing the voltage measurements on our multimeter, we realized that the voltage dropped to about 7 volts! Further investigation also shows that the voltage fluctuation (drops and spikes) caused by the PWM motor control signals greatly effect the camera, because when the motors are at 100% duty cycle (no fluctuation), there was less interference. Then, a member of the team suggested that we place a low ESR capacitor as near as possible to the camera to smooth out the voltage fluctuations. This solution worked and now the camera works perfectly, without impaired vision.

Challenges

By far the greatest obstacle we encountered was the waterproofing aspect of the entire ROV. While dry-testing the robot nearly always resulted in success, the robot was, for a length of time, completely unusuable underwater due to a certain leak that was not immediately obvious in our first few tests.

Despite this year's 力 ^{3} ROV being an adaptation of last year's 力 ^{2} ROV, a great deal of modifications have been made to the eletronics box, almost all of which involve cutting out the sides and installing new panels. While it would be possible to simply forget about the modifications and follow a design more similar to that of last year's, we ultimately decided that the benefits outweighed the costs of troubleshooting.

Assessing the situation of the electronics housing, we reckoned that it was possible to over-apply silicone sealant on all possible openings, just to be safe. However, past experience has taught us that this "overkill" method of waterproofing is not as safe as it seems, and without careful planning it potentially causes an ever worse problem without solving the original problem.

In the end, we decided to isolate the source of the problem. This method involved submerging the bottom half of the electronics housing underwater – safely, of course – and bringing it back after a short length of time. After doing this, we used our own leak detectors to find out which area of the housing was most moist. After a considerable amount of investigation, we found that the motor-connectors were the breach in the box's waterproofing, which we changed with a set of newer ones and re-applied a layer of silicone sealant on.

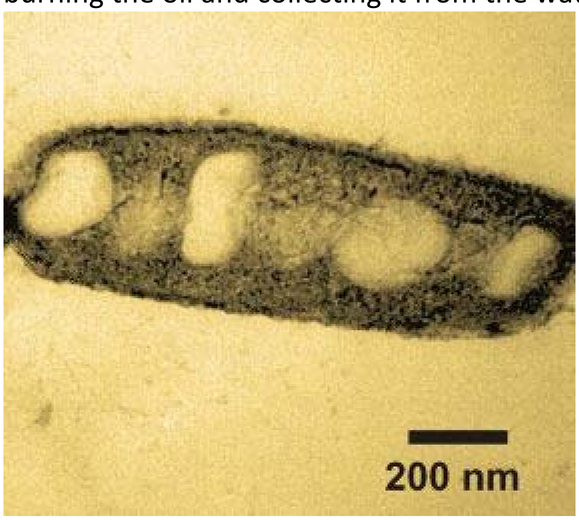
Another challenge that we have always had with the MATE ROV competition is the issue of time, which was a far graver issue this year than it was in the previous two. Not only were the original members of the team tied down with greater responsibilities (college, exams, etc), a lot of time that could have gone into working onto the ROV instead went toward teaching and training the newer trainees. While the sacrifice was rewarding, it still ultimately affected the overall state of the robot.

About Deepwater Horizon – *The "Oil-eating microbe"*

The disaster at the *Deepwater Horizon* offshore oil drilling rig is generally regarded as the greatest accidental oil spill in the history of the petroleum industry. Caused by a wellhead blowout, it was estimated that, from April 20 till July 15 of the same year, 53 thousand barrels of crude oil escaped into the sea every day.

An oil spill of this magnitude was undoubtedly going to cause a great deal of damage to the environment. From wildlife and marine habitats to the Mexican Gulf's fishing and tourism industries, the oil spill's affect on its surroundings was devastating on an unprecedented scale. Even today, it is not uncommon to find tarballs wash up the coast of the Gulf.

Given the magnitude of the disaster, it is no surprise that the scale of the reponse and effort put into reducing the effects of the spill was massive as well. Many different approaches were taken to tackle the spill, with mixed results. One method was containment, where temporary floating barriers (booms) were deployed to block the oil from entering ecologically sensitive areas. Another method of tackling the disaster is dispersal. While spilled oil naturally disperses due to certain natrual phenomena (such as storms and the ocean current), chemical dispersants have been used to expedite the natural process. Yet another method was simple removal of the oil. The types of removal includes burning the oil and collecting it from the water (skimming).



Above: One of the types of *Alcanivorax* – *Alcanivorax Borkumensis.*

With all the hustle and bustle taking place in the Gulf during the rescue efforts, few noticed that, unseen by the naked eye, Nature has its own ways of cleaning up oil too. Named *Alcanivorax*, this oil-degrading marine bacterium is said by some to probably be the world's most important oil degrader. A relatively recent discovery, *Alcanivorax* is an extremely rugged bacterium, being able to survive in supersaline parts of the ocean – parts that have an abnormally high concentration of salt that would normally inhibit the proliferation of cells. *Alcanivorax* is rarely ever observed in most ares of the ocean, especially in places that are completely devoid of pollution by hydrocarbons. Yet, wherever the ocean is suddenly plagued by high doses of these n-alkanes (chemical compounds that consist only of carbon and hydrogen), *Alcanivorax* thrives and consume these chemicals with its oil-degrading enzymes.

While the true capabilities of *Alcanivorax* is still controversial, its "oil-eating" effects have been universally recognised. Regardless of whether Mankind or Nature was the greater factor in tackling the problems created by the *Deepwater Horizon* oil spill, one cannot dispute that *Alcanivorax* was and will continue to be a big player in saving the world from our own petroleum-dependent habits. *Alcanivorax* truly is the unsung hero of the worldwide struggle against petroleum-borne disasters.

Reflections

Ryan Mok, Year 8

Throughout the process of creating our ROV, I have learned more about the process of designing and creating robots. This includes how the robot works, the creation process of making the robot, and the skills and tools needed to create the robot. I have learned a variety of skills and how to use different tools. For example, I learned how to use drills, saws, and how to solder. Using these different techniques, I have contributed to help the creation of the robot.

I found the creation of the robot fun and entertaining, as I get to use what I have learnt and apply it to the robot. It is fun watching it being put together with our effort and slowly seeing the robot come together bit by bit.

In conclusion, throughout the process of creating the robot, I have learned more about designing, creating, and different skills used to create a robot, which is a fun and entertaining experience.

Ariana Claire Barreau, Year 9

As I am new to making any of these types of robots, I have been able to get a good learning experience after going through the tiresome process of making the robot. It has taught me how to work hard together as a team and to be able to help each other when someone is lost to get a job done on time.

Just before actually making the robot, I was taught the basics of programming. I think this was the most challenging part for me, because I became quite confused with all the loops and equations that are used. This was soon resolved after a few more classes to practice programming. While planning the robot, I also learnt the functions and different parts of the robot that needed to be made. So from the experience I have gotten from this year, I am hoping that next year I will have more knowledge of what to do and what to expect for the competition, that I will be able to know what to do and what needs to get done independently.

Yumi Tang, Year 8

I have learnt a lot while making the robot and before we started this project. I have learnt about all the parts of the robot and the circuit system we have used for this project. Also, before this robot, I
learnt about the programming code and how to write it using the arduino which was used for this robot.

I learnt some simple skills like to crimp wire and others that I was mainly in charge of doing. I really enjoyed the process in making the robot in general. Everything I did was fun.

Financial Report

#	Part	Quantity	Unit	Reused value (HKD)	Donated by	Cost (HKD)
1	Arduino nano	1	N/A		N/A	200
2	RS232 Chip	1	N/A		N/A	12
3	DPDT relays	6	N/A		N/A	96
4	N-channel MOSFET	6	N/A	42	N/A	N/A
5	Fuses	8	N/A		N/A	16
6	Copper plates (20x20cm)	2	N/A		CIS	N/A
7	Aluminium square tubes	3	Metres		CIS	N/A
8	PVC Box (15.24x20.32cm)	1	N/A		N/A	200
9	Misc electronics (resistors, capacitors etc)	N/A	N/A	200	N/A	200
10	Stainless steel screws & nuts	12	N/A	40	CIS	N/A
11	Digital multimeter	1	N/A	N/A	N/A	60
12	USB to Serial dongle	1	N/A	14	N/A	N/A
13	CCD Camera	1	N/A	300	N/A	N/A
14	3, 6, 9mm acrylic	N/A	N/A	N/A	CIS	N/A
15	500 GPH Bilge pumps	2	N/A	N/A	CityU	N/A
16	Black and red 10AWG	30	Metres	246.06	N/A	N/A
17	CAT5	15	Metres	147.64	N/A	N/A
18	Motor mounts	8	N/A	16	N/A	N/A
19	Honeywell ASDX030	1	N/A	N/A	N/A	200
20	1000 GPH Bilge pumps	8	N/A	N/A	Trac-Marine	N/A
21	Propellers	8	N/A	64	N/A	N/A

Total costs: **1021HKD** (disregarding costs of items reused and donated)

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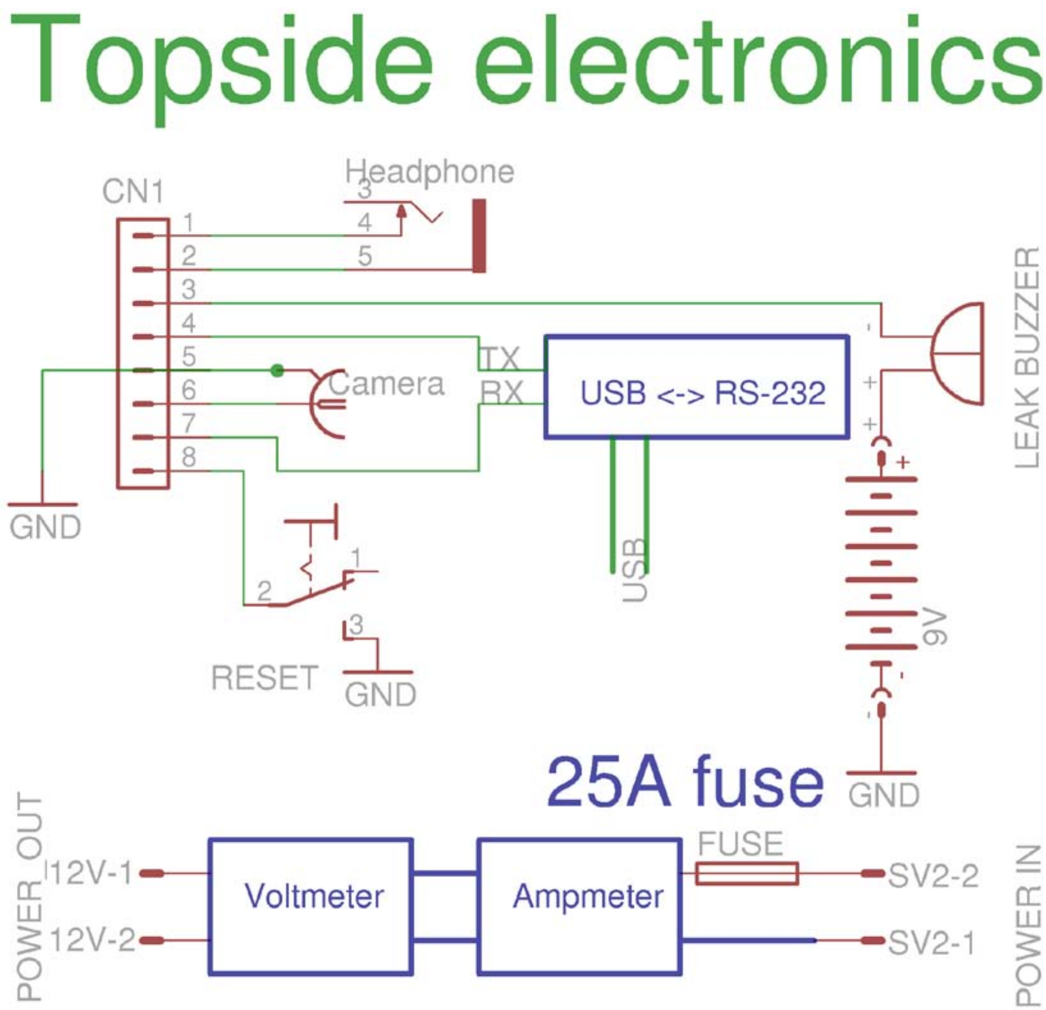
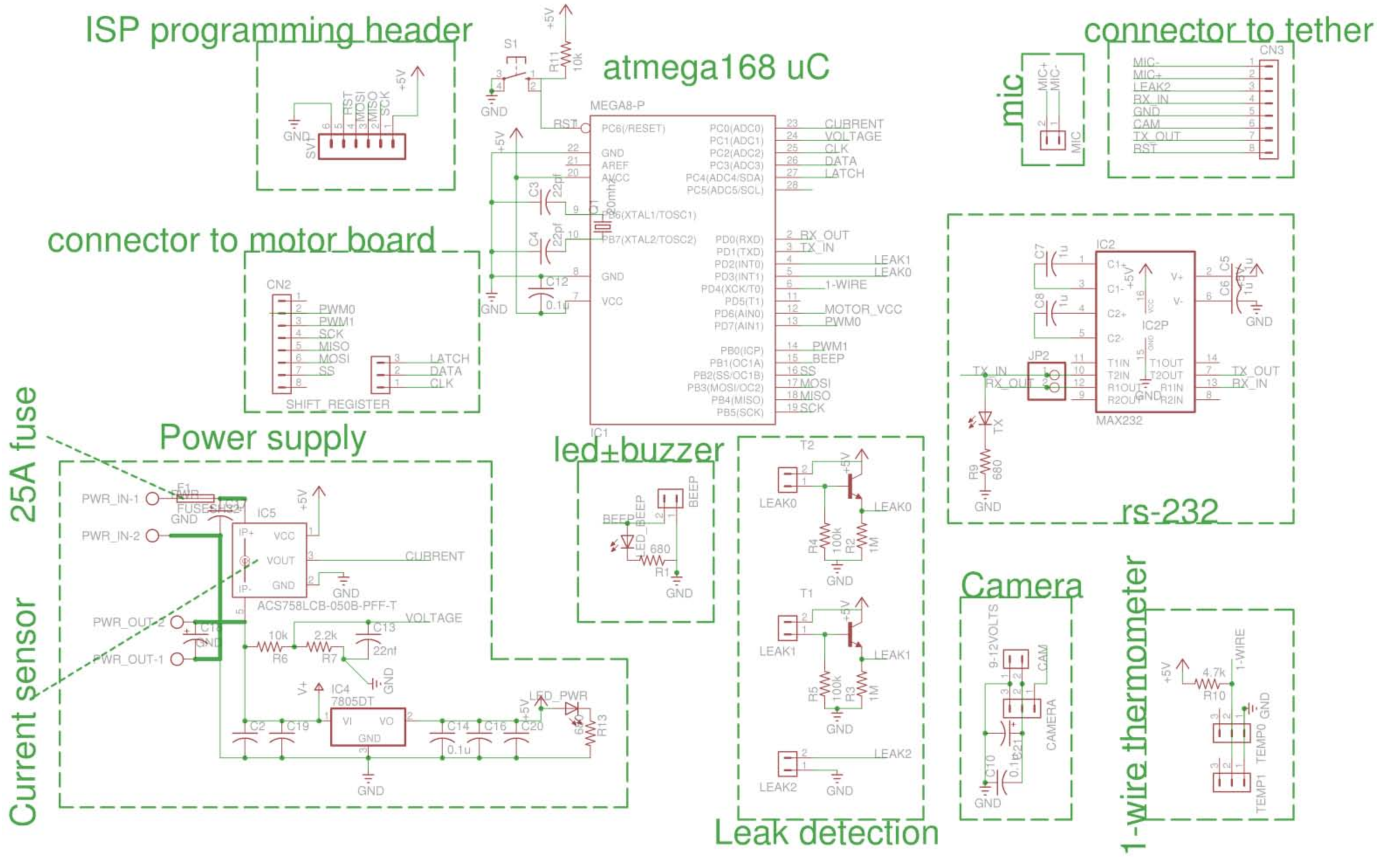
Appendix

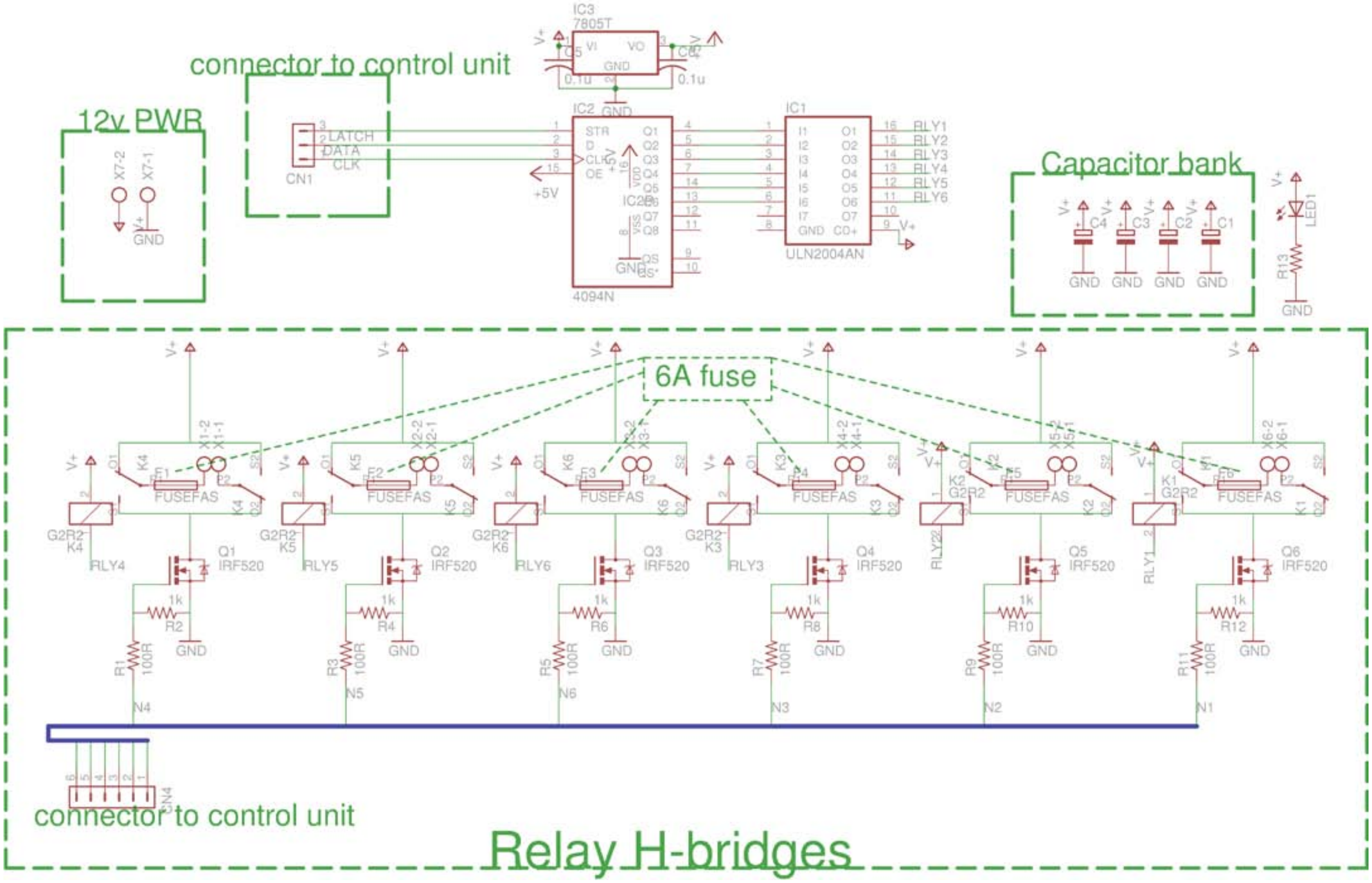
Electronic / electrical schematics



Control Unit Schematics



Motor controller schematic



Software Flowchart