Technical Report

10th MATE International ROV Competition, Houston, 2011

ROV Name: Leviathan
Company Name: The Claw of the Dragon
City University of Hong Kong

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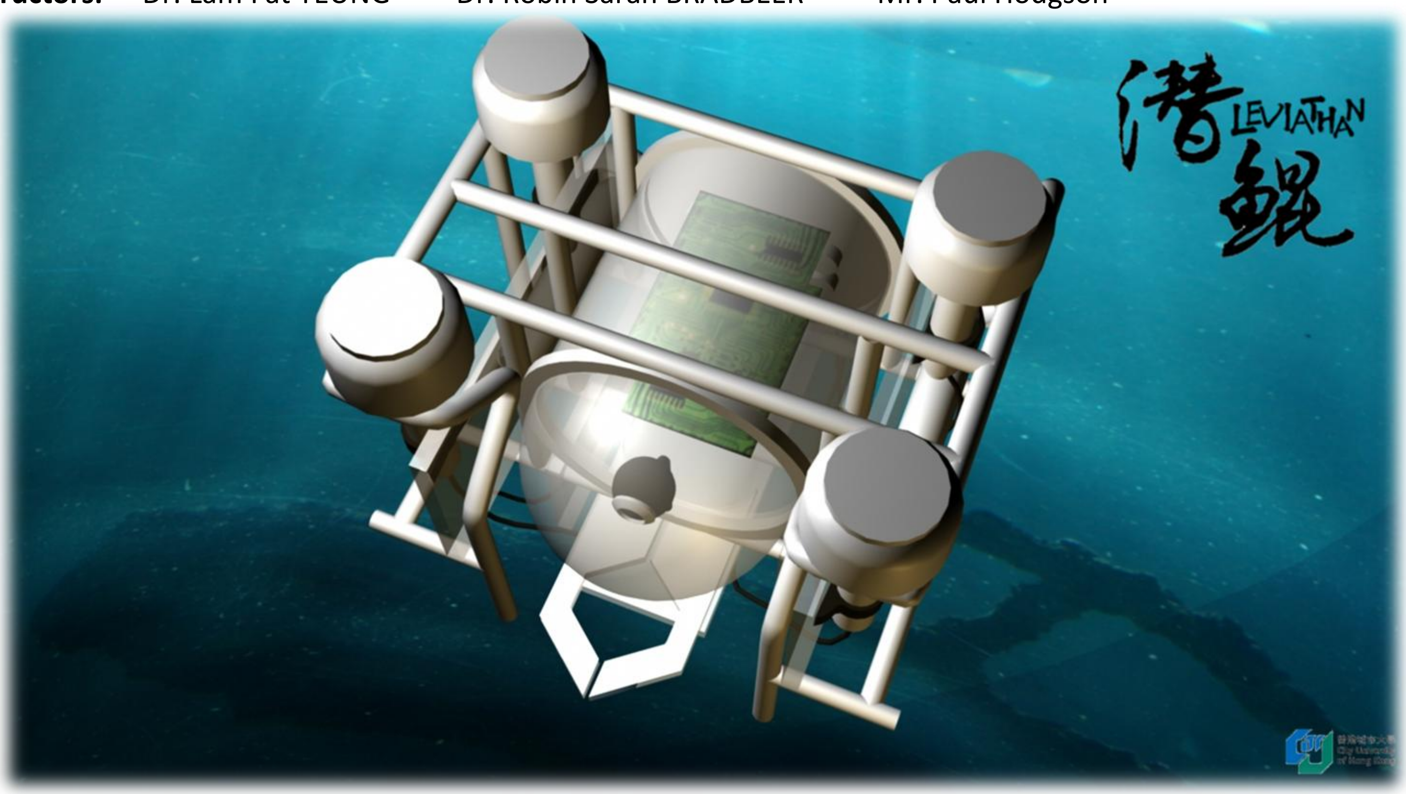


Abstract

A remotely operated vehicle (ROV) named Leviathan in English, 潛鯤 in Chinese, was designed and built by the team "The Claw of The Dragon" for the 10th MATE ROV Annual Competition in Houston, Texas this summer. The ROV is able to be controlled by only one pilot with game controllers on laptop computer or other kinds of devices such as smart phones, MIDs and PC. The tether is 20 meters long and consists of three wires. One is a typical LAN cable and the other two provide 48V power for the ROV. The designed working depth of the ROV is 12 meters. There are four vertical thrusters providing 10N force each and two horizontal thrusters with 30N force each, and making both the attitude and movement of ROV controllable. The manipulators were specially made for the tasks in the competition and they are replaceable in order to adapt to different situations. The ROV can be self-controlled and communicate with the outside via Internet.

Content

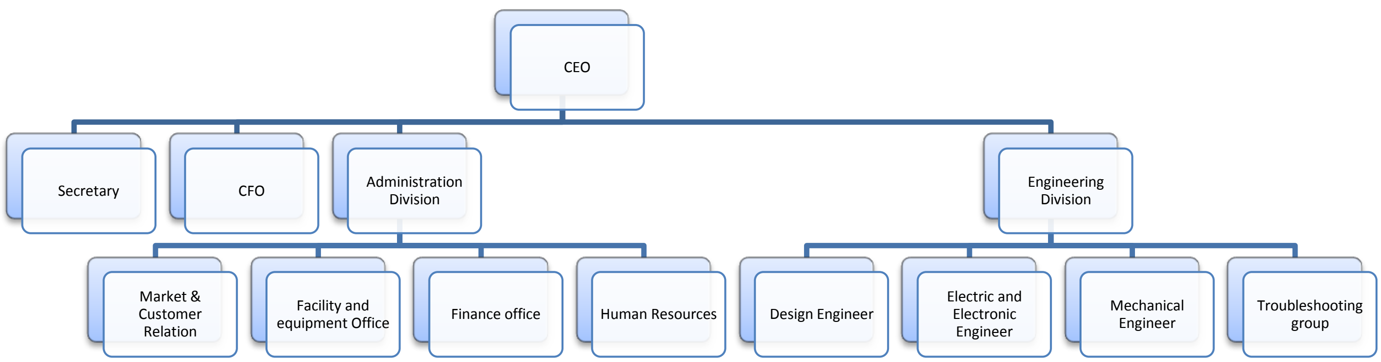
Introduction

1. The Company

For better learning experiences in building up this year's ROV, a fake company was set up. The whole team now is working as a commercial company so that it is the first time we treat engineering projects as a business. Team members now have their own unique roles and the working efficiency of teamwork is expected to be higher.

The company has two divisions, namely administration and engineering. The administration division is taking up everything that does not directly related to the design, manufacture and other engineering issues, i.e. budget and expenditure control, fund raising, public relations and communications. Although it is not technical, the administration division still involves in engineering and it helps make the demand of customers clear, settle the equipments and workspaces that needed and target the market. The engineering division is responsible for the design of the ROV, and gives solutions to different tasks on demand.

Illustrated by the following chart, the company has a clear hierarchy of organization.



The objective of the company is making profit by providing solutions for underwater tasks. These tasks include exploring, video recording, measuring and surveying, rescue and repairing in deep fresh waters like river, lake or pond.

The motto of the company is "Technology Makes Life Easier". The further development of the company is that the operation range will be widened and the operation manner will be easier. We have an idea that customers should be able to control the ROV by themselves easily and operate it on land, in lakes and seas, or even in ocean. Without professional training, it is possible that users may know how to operate the ROV as long as they touched the control panel, just as they touched an XBOX controller and know how to play a video game. We make sure that our products are of good quality and by several trails the customers are capable to do tasks by themselves. Not only the ROV design and produce, the company also provides educational presentations and exhibitions for juniors and the public. It is noticed by the public these days that ocean science is a wonderful new area to human natures, and people do need to know more about it as ocean covers 71% of the earth surface. The importance is that people should properly treat the ocean and develop it sustainably.

2. Demand

In this year's particular competition, the scenario was set that we were going to give a solution for the crisis at the oil stations in Gulf of Mexico. A well designed ROV is needed that it is able to take tasks such as simple maintenance of the oil pipes and collect water samples. It is required that the ROV is stable and precise for operations. Since in the competition, the operation environment was relatively easy for ROVs as the tasks are in fresh water pool and the water is static so that the waterproof and power requirements are not as strict as if we build a real work one. However, the basic demand is that the ROV we built should be easy to be operated underwater. It should be capable, stable and controllable and extendable.

It is noticed that if one ROV could be easily adapted into different scenarios, it would be saving a lot of resources and time. The idea is that to build an ROV once and use it many times. The only changes need to be made are the manipulators and their corresponding drivers. It is important to run a sustainable business in modern days in order to make more profit.

3. Product Specifications

ROV

- Name: Leviathan
- Chinese Name: 潜鲲
- Weight: 30kg
- Dimension: 50cm(l) x 50cm(w) x 50cm(h)
- Number of Pilot: 1
- Number of Cameras: 3
- Number of Manipulators: 3 (different purposes)

General

- Wired operation to 20m fresh water depth
- At least one manipulator able to pick up things underwater
- Depth and attitude adjustable and lockable
- High quality video
- Control via Internet or local network
- Controlled by joysticks or joypads at the terminal

Features

- The design is sustainable, i.e. the system can be extended for different missions by replacing the manipulator module. Other modules can also be replaced or updated for different functions
- Semi-automatic motion, i.e. lock to a depth and lock the attitude for special tasks
- Transparent control interface via LAN cable, can be extended to the Internet
- Able to be controlled by different terminals, including laptop, tablet and mobile phones

Mechanical and Electric Specifications

Waterproof Box: At least 20cm*20cm*10cm in volume, 2 Bar waterproof
Power supply: 1 Pair providing 48VDC maximum 40A

Communication cable: 1 CAT-5e/CAT-6 SF/UTP Cable Transmitting 802.3 Ethernet Signals
Robot Arm: 1 robot clamp
Thrusters: 2 Large Thrusters working with 48VDC 6A maximum providing 30N force
6 to 8 Small Thrusters working with 48VDC 3A maximum providing 10N force

Electronic and Control system Specifications

Cameras: 2 Wide-angle HD cameras and 1 analog camera
Main Control Unit: Embedded system, with video processing and control signal processing, 12V 3A
Driver Unit: With private microcontrollers, decode the instructions from Main Control Unit and give power/direction adjustable output
Sensors: OS5000 Digital Compass with 3-axis accelerometer, magnetic field coordinates, temperature, headings angle
Pressure Sensor ASDX030G24 for depth

Main control unit specifications

Platform: Intel® x86 Atom™
OS: Microsoft Windows XP sp3 (modified version)
CPU: Intel® Atom™ processor D525
http://ark.intel.com/Product.aspx?id=49490
RAM:2G DDR2/3
Storage: 2.5’ SSD and USB Flash disk
Serial Ports: 4 provided by a PCI peripheral card
Network Port: 10M/100M on-board LAN adaptor

-No cooling fans on the board
-Estimated Total Power 35W
-Supplied by a 12VDC-to-ATX Power module
-Start up time (Power up to control programs loaded): less than 30s maximum 45s

Program Platform: Microsoft .NET 2.0 Framework, DirectX9.0c

The software for the main control unit will process:
-Receive – Network – Control commands
-Transmit – Network – Real time image from cameras, sounds and status data
-Transmit – Serial Port – Motor Driver Signals
-Receive – Serial Port – Digital Compass
-Receive – Serial Port – Pressure sensor, Leakage sensor and Power supply Sensor and other sensor data

Size: 17cm*17cm*5cm

4. Engineering Schedule

The engineering schedule was made at the very beginning by the team student manager Gus in October 2010. During the project period several points of time was slightly adjusted however most of the works were done on schedule.

Event	Period
Preparations for new ROV Competition	August 2010 – January 2011
Release of missions	Mid December 2010
Design of a workable ROV, specification	January 2011
Team member recruitment and kick-off meeting	26th January 2011
Mechanical and waterproof engineering	February 2011 – Early April 2011
Electric engineering (Power systems, Motor drivers)	February 2011 – Early April 2011
Controlling system including electronics and software	February 2011 – May 2011
Start of Documentation	Early April 2011
Demonstration	9th April 2011
First whole system underwater trail	Mid April 2011
Control system debug, adjustment and correction	Mid April 2011 – May 2011
Backup modules fabrication	May 2011
System testing	Early June 2011
10th MATE ROV Competition at Houston	14th June 2011 – 24th June 2011

5. Budget and Expenditures

The budget list was made with the project plan in the very first place and later the fund was raised by the teammates. The actual expenditures are less than the original budget since the team has not raised enough funds.

a. Budget

	Unit Price	Qty.	Sum	Subtotal
Central Control Unit				
Intel Atom D525MW mother board with CPU	HK$700.00	2	HK$1,400	
Kingston DDR3 1333MHz 2G	HK$200.00	2	HK$400	
Corsair solid state disk F60GB2	HK$1,000.00	2	HK$2,000	HK$3,800
Controllers				
Control pad (XBOX360)	HK$370.00	2	HK$740	
Motion Controller (Wiimote)	HK$180.00	2	HK$360	HK$1,100
Power supply				
DC-ATX power supply board	HK$200.00	2	HK$400	
DC converter 48 to 12 modules	HK$500.00	4	HK$2,000	
AC220V to DC48V 2000W	HK$2,500.00	1	HK$2,500	HK$4,900
Electronics				
IRF3205 power mosfet	HK$10.00	100	HK$1,000	
PCB boards	-	-	HK$1,000	
STC89C52RC Microcontroller PQFP44 package	HK$10.00	10	HK$100	

Connectors	HK$100.00	10	HK$1,000	
Other parts	-	-	HK$500	HK$3,600
Video Cameras				
Microsoft High-res Video Cameras	HK$400.00	3	HK$1,200	
Wide-angle analog video camera	HK$500.00	1	HK$500	HK$1,700
Mechanical				
300W Brushed waterproof Motors	HK$5,000.00	3	HK$15,000	
72W Brushed waterproof Motors	HK$2,000.00	8	HK$16,000	
Angular motors for manipulators	HK$2,000.00	5	HK$10,000	
Operation Arms	-	-	HK$2,000	
Other parts	-	-	HK$1,000	HK$44,000
Sensors				
Pressure sensor	HK$500.00	2	HK$1,000	
Temperature sensor	HK$25.00	2	HK$50	
Water leakage sensor	HK$10.00	2	HK$20	
Power sensor	HK$100.00	2	HK$200	HK$1,270
Case				
Underwater housing	HK$10,000.00	1	HK$10,000	
Waterproof connectors	HK$25.00	20	HK$500	
Cooler pad	HK$200.00	2	HK$400	HK$10,900
Wiring and Communication				
Power Lines	-	-	HK$1,000	
Cat-5e Shield Twisted Pair	-	-	HK$500	
Wi-Fi Router	HK$200.00	1	HK$200	HK$1,700
Misc.				
Tools, Utilities and Equipment			HK$10,000	
Specialized Power Supply			HK$5,000	
Shipping and transportation			HK$3,000	
Transportation			HK$1,000	
Communication			HK$1,000	HK$20,000
Total				**HK$92,970**
Promotion Expense				
T-shirts and souvenirs	HK$7,000.00		HK$7,000.00	
Posters and banners	HK$500.00		HK$500.00	HK$7,500.00
Total				**HK$100,470.00**

In the very original design, most of the parts were designed to have at least one exactly identical backup. This basically doubled the final cost. However, the team members thought that it is necessary as the ROV will be shipped from Hong Kong to Houston and in case that some parts were broken.

b. Deposit and Expenditures

The funds were raised during the project period. A sum of HKD30000 was raised in total.

Donator	Amount

Department of Electronic Engineering, City University of Hong Kong	HKD20,000
Dr. L F Yeung	HKD10,000

All the materials that have been bought till 19 May 2011 are listed in the following table. Since the team now is still seeking for sponsorship, quite a lot of parts are not bought. These parts are mainly used for backup, including one more waterproof case and more waterproof thrusters.

Receipt No.	Date	Detail	Amount	Ratio	Sum
20595	2/12/2010	Wii Wireless Controller	180	1	HKD 180.00
0012388	29/12/2010	XBOX360 Controller	310	1.19	HKD 368.90
B411A00545	10/1/2011	Intel Atom D525 NM102X Mother Board	699	1	HKD 699.00
B411A00545	10/1/2011	Kinston 2GB DDR3	180	1	HKD 180.00
N/A	10/1/2011	500rpm Bilge Pump From last year's project	0	0	HKD 0.00
N/A	10/1/2011	Waterproof Cameras From last year's project	0	0	HKD 0.00
N/A	11/1/2011	MIC4420BN	60	1.19	HKD 71.40
152551	11/1/2011	CORSAIR 60GB SSD	995	1	HKD 995.00
000382	16/1/2011	1x40 socket	25	1.19	HKD 29.75
0013100	16/1/2011	Radio Transiver	390	1.19	HKD 464.10
0000914	16/1/2011	IRF3205 MOSFET	25	1.19	HKD 29.75
0000914	16/1/2011	BC547	5	1.19	HKD 5.95
017647	18/1/2011	Wheeled board	95	1	HKD 95.00
0014126	21/1/2011	Radio Transiver	180	1.19	HKD 214.20
0014126	21/1/2011	Data Downloading Wire	30	1.19	HKD 35.70
0037312	7/2/2011	Wireless Router W268R	95	1.19	HKD 113.05
25322	23/2/2011	Arcylic Pipe d=250mm x 1220	1000	1	HKD 1,000.00
25322	23/2/2011	Arcylic Board 4.5mm 1000x250	60	1	HKD 60.00
591205461477	4/3/2011	Semisphere Case with shipping	81	1.19	HKD 96.39
0044914	24/3/2011	Electromagnetic Lock	276	1.19	HKD 328.44
0023379	26/3/2011	JQX-115F-2Z54 5V Relay	130	1.19	HKD 154.70
N/A	26/3/2011	MIC4420 SOP	174	1.19	HKD 207.06
N/A	26/3/2011	MUR100	25	1.19	HKD 29.75
N/A	26/3/2011	4N26	20	1.19	HKD 23.80
0905128	26/3/2011	Fuse Base	20	1.19	HKD 23.80
0004927	26/3/2011	Semiconductor Cooler	60	1.19	HKD 71.40
0010823	26/3/2011	IRF3205 MOSFET	50	1.19	HKD 59.50
0010823	26/3/2011	BC547	10	1.19	HKD 11.90
SA1103300030	30/3/2011	DMM	79	1	HKD 79.00
SA1104080236	8/4/2011	Electronic Parts	44	1	HKD 44.00
SA1104080272	8/4/2011	RCA Sockets	16	1	HKD 16.00
N/A	14/4/2011	WaterProof Cases Donated by 10Bars Co.,Ltd.	0	0	HKD 0.00
0110193	20/4/2011	Servo Motor	30	1.19	HKD 35.70
26181	6/5/2011	12mm Arcylic 1m x 1m	700	1	HKD 700.00
26181	6/5/2011	Arcylic Cylinder 2m	60	1	HKD 60.00
CM76521	6/5/2011	Tamiya -TA05 ver II Low	49	1	HKD 49.00

CM76521	6/5/2011	Team C Carburettor Spring	15	1	HKD 15.00
CM76521	6/5/2011	JPL Manifold Sping for .12	15	1	HKD 15.00
277791	9/5/2011	Wood Ruler with clinometer	38	1	HKD 38.00
62779	10/5/2011	PVC pipes	102	1	HKD 102.00
N/A	10/5/2011	PVC connectors	60	1	HKD 60.00
N/A	13/5/2011	WaterProof Thrusters	19500	1.19	HKD 23,205.00
0183162	13/5/2011	1:10 gear box	65	1.19	HKD 77.35
0183163	13/5/2011	1:10 gear box	65	1.19	HKD 77.35
Total					HKD 30,121.94
Appr. In US$					USD 3,873.68

Design and Implementation Details

In this session, the details of the design and implementation of the ROV-Leviathan are presented in three parts, i.e. “Mechanism”, “Electric and Electronic” and “Software and Control System”. The “Mechanism” topic mainly introduces the “Hardware” of the ROV, including the framework, the waterproof capsule, manipulators and thrusters. The “Electric and Electronic” part illustrates how electronic circuits drive the peripherals and how sensors transmit signal back to the controllers. The “Software and Control System” part explains how the control system works and the features of the software brought by our team.

1. **Mechanism**
    a. Framework

The framework of ROV-Leviathan is made by PVC pipes, PVC connectors and acrylic boards. The diameter of PVC pipe is 20mm and the thickness is 3mm. The thickness of acrylic board is 12mm. The parts are connected together by 6mm diameter screws. The overall dimension is 50cmx50cmx50cm and inside the framework there are rooms for the waterproof capsule and the thrusters. Both waterproof capsule and thrusters are fixed firmly on the framework. The framework was carefully designed that it would protect most of the important devices and make sure all the peripherals are solidly contacted. The main-framework holds the waterproof capsule and all the thrusters.

One important change in design from last year’s is that the manipulators were fixed on a sub-framework that is connected to the bottom of the main-framework. The sub-framework can be easily removed from the body and if there are several different tasks need to be implemented by different manipulators, these sub-framework modules are interchangeable.

    b. Waterproof Capsule

Almost all electronic devices are enclosed in the big waterproof capsule which is designed for 2 bars water resistance. The internal space is a cylinder with 28cm in height and 23cm in diameter plus a 10cm in radius semi-sphere. The material is basically acrylic and aluminum. Acrylic was chosen because of its great strength and transparent characteristics that would be suitable for cameras.

There are two aluminum pads and the acrylic cylinder was nipped by them and sealed by two O-rings at each contact surface. At the other side of the front aluminum, the semi-sphere acrylic is also sealed with O-ring. There is a big hole on the front aluminum pad so that the two spaces are together and all the waterproof connectors are made on the back aluminum pad. There is also a space on the back aluminum pad designed for cooling devices. Since aluminum is a good conductor of heat, all the heat produced inside the capsule by the electronic devices will be transferred into the water outside via the back aluminum pad. The details of how heat is effectively transferred will be introduced in the "electric and electronic" session.

c. Buoyancy

The overall volume of the ROV is approximately 30 liters, thus the overall weight must be around 30kg. However, the sum weight of all the devices is less than this value. Additional payloads are added according to tests in water. The ROV is adjusted to be neutral buoyancy in water for freedom of movement.

d. Manipulators

i. *Mission One – Hook*

To transport and attach a line to the U-bolt on the damaged riser pipe, a clip similar to key buckle is used.

The hook is fixed at the bottom part of the robot. With a camera at the bottom, the relative position of the hook to the U-bolt can be monitor. After the hook clasps the U-bolt, the robot will be driven to rise up and lift the pipe from the work area.

ii. *Mission Two – Cap*

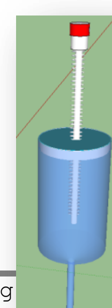
The Cap is composed of four arms and one spring plate.

The four arms originally stick to the bottom of the robot by four electromagnets; after moving the robot to the position directly above the wellhead, the power to the electromagnets will be cut and the arms fall down and stick to the outer wall of the wellhead. Then the robot moves away from the well head and will release the spring and the spring plate fixed on the arms bounce back and covers the hole afterwards.

To make sure that the four arms can provide enough resistance force against the pipe, strong magnets are used. Besides, soft rubbers are used at the contact positions inside the arms. The total force need to be provided by this mechanism should be up to 150N as the oil pressure inside the pipe is 2.4bars maximum.

iii. *Mission Three – Sample Collector*

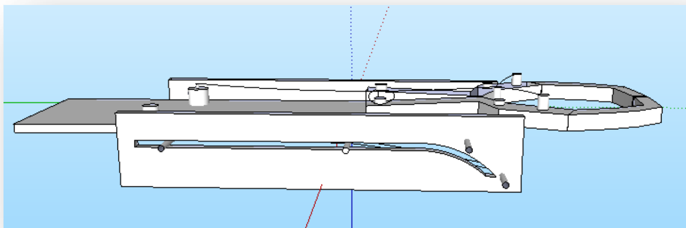
The water sampler is composed of a rotating motor, one storage tube similar to an injector and one long screw connected both the motor and the piston inside the storage tube.



After inserting the sampler into the container, the piston will be driven up by the motor and water sampled will be stored in the tube.

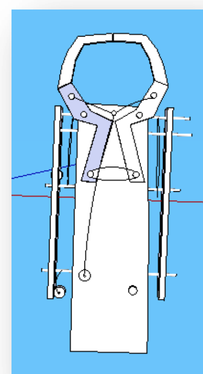
iv. *Mission Four – Clamp*

The degree of freedom of the manipulator are moving forward and backward (surging) dimension and a 90 degree turning left and right (yawing) dimension. The x-y plane stretch out and drawback is fulfilled by a 20cm slide way. The yawing dimension is accomplished by a 75 degree slope of the slide way. While the x-y plane rotation and the z-direction movements are adjusted by the angle and depth of the robot respectively.

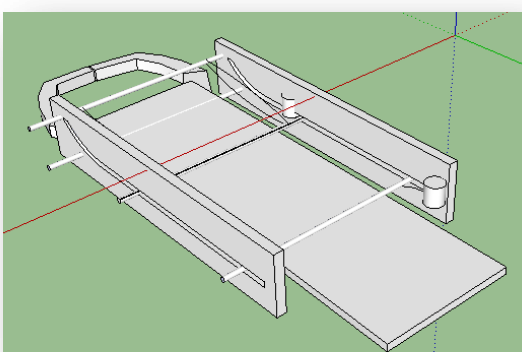


To motion to push out the arm or pull back the arm is driven by a motor at the back part of the manipulator. And the action of grab is accomplished by the clamp at the upper and a drive motor on the fixing plate.

The clamp is originally closed up by the spring connecting the two endings of the clamp. After receiving the closing signal, the wire connecting the two fingers is pulled in by the motor and the claw will close up.



Reducing gear is applied so that coronation of the motor closes up the two fingers while only contra rotation of the motor will release the wire and stretch the two fingers. The use of reducing gear permits the motor to stop spinning after the clamp is closed up since the wire will not be released until the contra rotation of the motor.



The plate which the clamp is fixed on is immobilized by two sticks passing through the slide way. Similar design to clamp grab, reducing gear is applied that the spring connecting the gliding stick and the stick fixed on the slide way is originally stretched; the contra rotation of the drive motor will release the wire linking to the gliding stick and the fixing plate will be pushed out while the co rotation of the drive motor pulls in the wire and draws back the fixing plate.

e. Thrusters

There are six thrusters used in total. Four 10N-thrusters are providing forces vertically at the four corners of the framework. These vertical thrusters are used to not only control the depth, but also the attitude of the ROV. According to former experiences in the competition, it is found that the attitude of the ROV is important when it is trapped by some obstacle. Nevertheless, it would also be very helpful if special attitude is needed for difficult tasks and movement such as twisting a handle, picking up parts on the riverbed and so on. On the horizontal direction, two 30N-thrusters are providing forces for moving forward, backward and turning around on the horizontal plane.

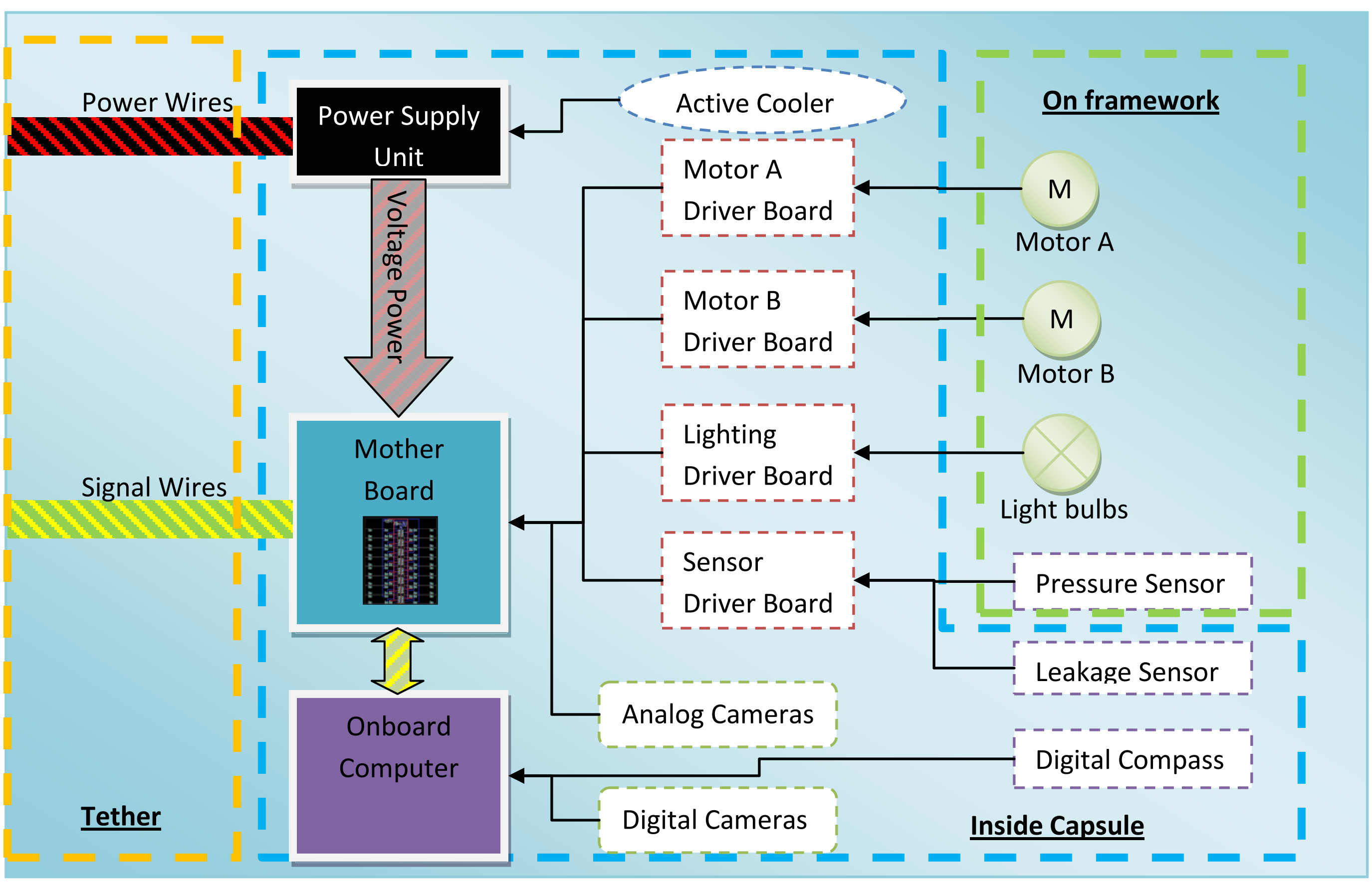
The power of two kinds of motors were carefully chosen that they are providing enough torque for movement of the ROV, meanwhile the current is not too large for motor drivers. The input power of 10N-thruster is approximately 72 Watt and for 30N-thruster the value is less than 300 Watt depending on the temperature, payload and the density of the water.

These thrusters are all made of waterproof carbon brush motors. The advantage of such motors is that they can be easily controlled with the power percentage and the directions. The output power percentage can be simply controlled by PWM voltages and the directions of the motors can be controlled by the direction of the electric current provided by the drivers.

2. Electric and Electronic

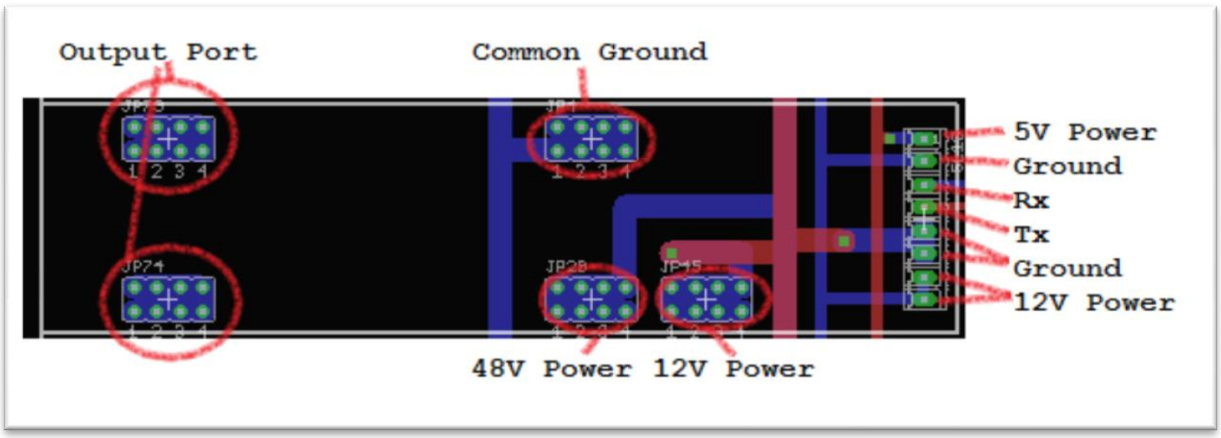
a. Overall Structure and Connections

The overall structure of electric and electronic system is clear and simple. On the outbound connection side which is the tether, it only contains two set of wires, power and signal. Inside the waterproof capsule, there will be the main electronics including the power supply, micro processors, driver circuits and cameras, etc. In the complete design, an integrated micro computer is also included inside the capsule so that many advanced functions are enabled. Illustrated by the following diagram, the main parts inside the capsule are the power supply unit, mother board, different kinds of driver boards, sensors, cameras and active cooler.



b. Mother Board

Just like the motherboard in a PC, inside the capsule, the mother board is a bridge between the input resources, e.g. control terminals, power supply, and the functional devices. Here the functional devices are different kinds of driver boards. There are 16 identical slots for different kinds of driver boards, each provides a signal line, a 5V power supply up to 1A, two 12V power supplies which one is up to 2A and the other one is up to 4A, one 48V power supply up to 5A and one pair of output ports. The connection between driver boards and mother board are 2.54mm standard jumper pins and sockets. Multiple pins are used for single port so that the allowed current becomes larger. This design enables fast replacement of driver boards that may easily get broken. It is also convenient for replacement of different manipulators since they may need their own corresponding driver boards. The good news is that the ROV gets extreme capability for expansion. Other parts remained, if a new peripheral device is added, just adding its driver board on the mother board and make the connections correct, it will be working.



On the outbound connection side, the mother board was connected directly with the power supply for different voltage sources. Also there is a signal bridge consist of a MAX232 signal transceiver and a MIC4420 MOSFET driver. The MIC4420 is used to enlarge the fan-out for the Rx signal line as it is shared by up to 16 micro processors.

c. Power Supply

The power supply from the tether is purely 48V DC however the devices inside the capsule may need different voltages such as 5V, 12V and 24V. For the 12V power, there are six bulk converters transforming 48V DC to 12V DC and each has capability of up to 9A. They are connected in parallel in order to have pure and stable current for the devices. For the 5V voltage, since it is mainly used for logic circuits and micro processors, the power consumption is relatively small. It is generated by L7805 voltage regulators. For the 48V power, only a large capacitor is used for smoothing the ripples.

d. Driver Boards

i. Standard Package

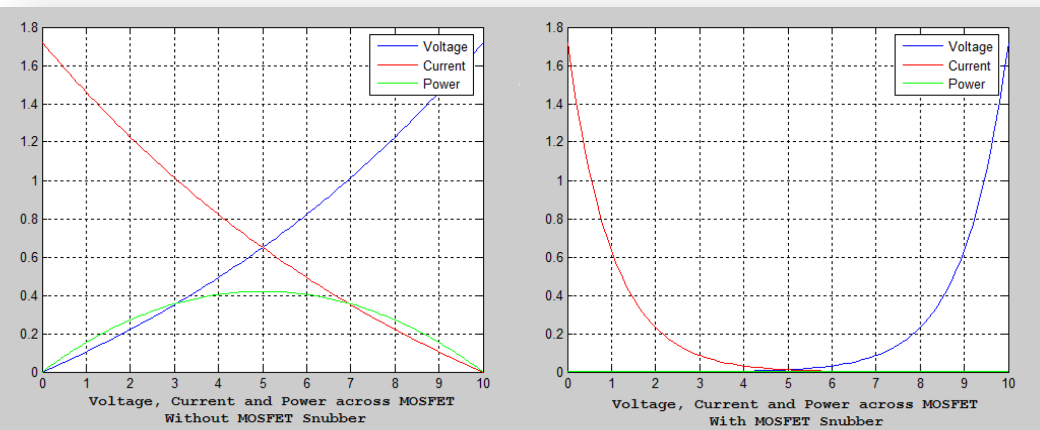
All the driver boards are all PCB boards of the same size, 2.54cm in width and 10.16cm in length. The only connection with the mother board is the jumper pins, as they provide both electrical power and signal and physical fixture. According to different uses, the driver boards may have all or parts of the jumper pins.

ii. *<u>Motor</u>*

The driver boards for motors are the most important kind. The function of motor drivers is controlling the output power and the directions of the motors, no matter a thruster or a motor on a manipulator.

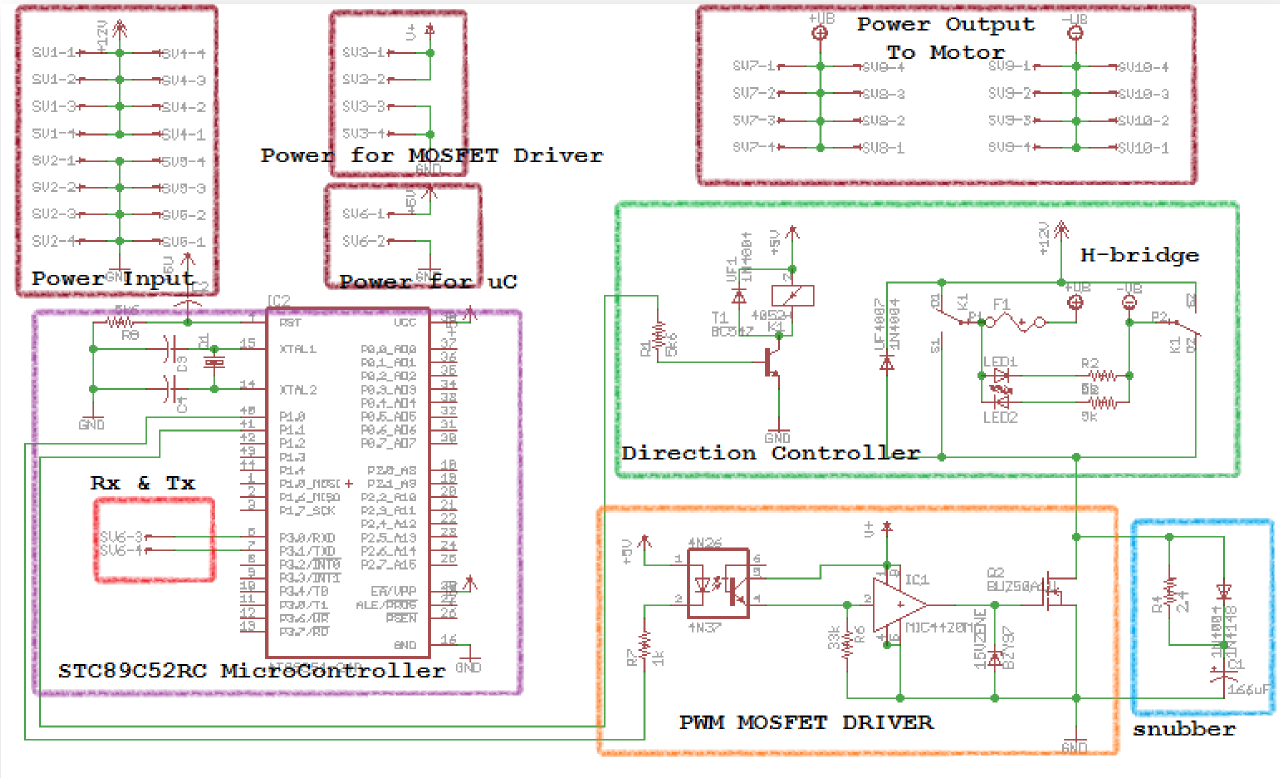
There are two kinds of microprocessors used for motor driver boards, both of which are of the exact functions. One is PIC12F874 which is a microchip product and the other one is STC89C52RC which is a standard MCS-51 microprocessor. The microprocessor receives the signals from Rx line on the mother board, and the outputs are one PWM (Pulse Width Modulation) signal and one CW (Clockwise) signal. The frequency of PWM signal is 250Hz with 5V maximum voltage. The CW signal is simply on/off.

For power controlling, the output current were controlled by the PWM signals from the microprocessor. An N-channel MOSFET IRF3205 is used to enlarge the current for driving the motor. It was found in experiment that if the PWM signal from the microprocessor directly drives the MOSFET, the MOSFET generates a lot of heat. This is because the equivalent capacity at the MOSFET gate cannot be fully charged and discharged instantly. According to the datasheet, during the transient state between the threshold voltage and zero, the MOSFET is partially conducting and produces a lot of heat. Another important reason of heat is that the instant voltage across the drain and source and current via drain are not in phase. Illustrated by the following image, with a MOSFET snubber connected across the drain and source, the power dissipated on the MOSFET is deduced significantly.



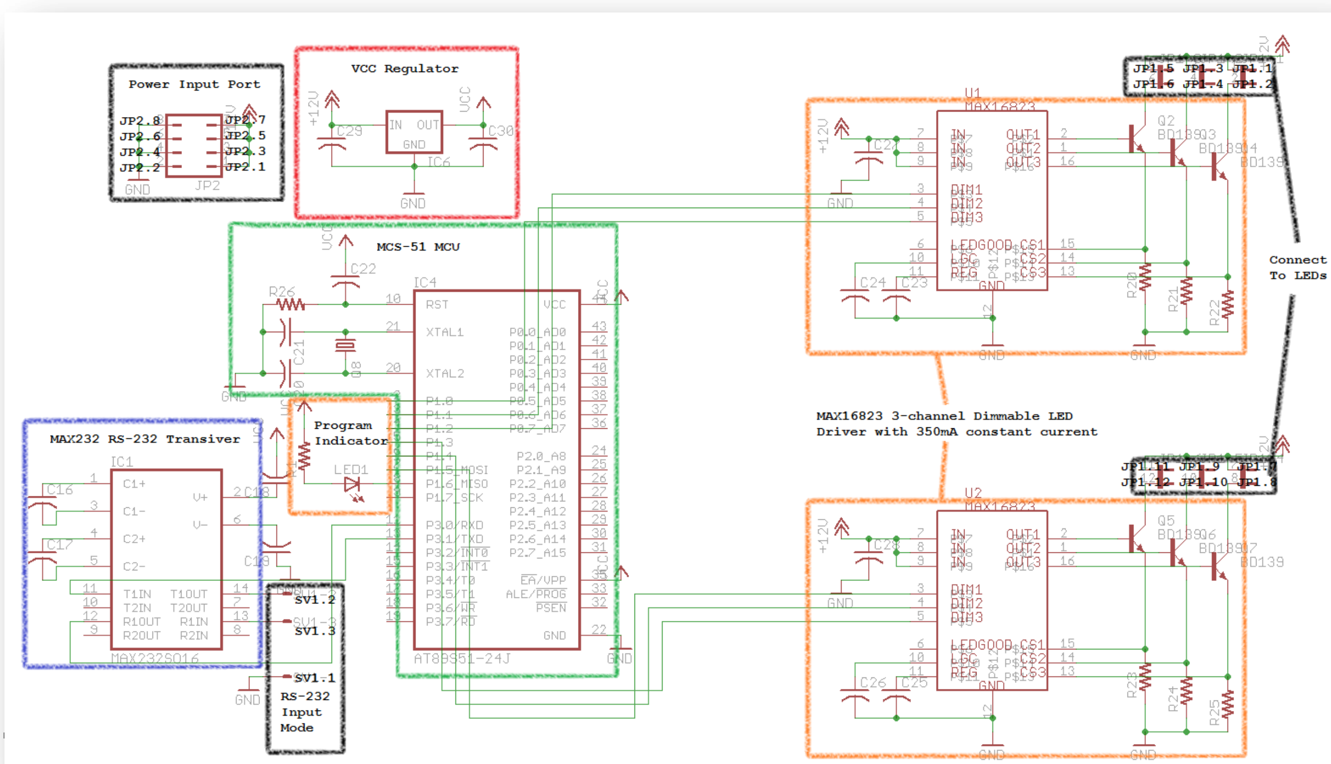
For the direction control, an H-bridge is used so that the current direction at the output port can be changed. It is simply a relay controlled by the CW signal from the micro processor. The current controlling the relay is enlarged by a BC547 NPN type transistor.

A typical implementation of driver board using STC89C52RC as the controller is shown in the following schematic.



iii. Lighting

The lighting driver board is similar to the motor driver board. A single STC89C52RC chip provides up to 8 channels of PWM signals for dimming of lighting devices. The lighting devices are 1W High Brightness LEDs work at 350mA. MAX16823, a three channel HBLED driver with dimming, is used to drive the LEDs. The following schematic shows how the driver board works.



The lighting driver board can drive up to six strings of LEDs, which the working currents are all 350mA. The six channels are all independent and are all dimmable from 0% to 100%.

iv. Sensor

The sensor driver board inside the waterproof capsule mainly transfers data from sensors to the on-land computer.

1. Pressure Sensor

To measure the depth of the ROV, a pressure sensor is used. The model number is ASDX030G24R from Honeywell. The working range is 0 to 30psi gauge which is approximately 20 meters depth in fresh water. The sensor is supplied by a single pair of 5V voltage. The output is an analog voltage signal varies from 0.8V to 4.5V. To minimize the distortion of the analog signal, an ADC is connected closely with the sensor, converting the analog signal immediately and sends back the signal to the sensor driver board. The signal used is RS-232 since it is relatively easy for signal processing.

2. Leakage Sensor

The leakage sensor is simply an open port with a BJT amplifying the current. The voltage drop at the sense resistor can be detected by the microcontroller at the external interrupt pin.

3. Digital Compass

The digital compass is an integrated sensor with 3-axis accelerometer and magnetic field meter. It is able to measure the pitch, roll and heading of the ROV. This feature enables advanced controls such as the attitude auto-adjustment. The digital compass is connected directly to the controlling PC since the data rate is large. The output signal is RS-232.

e. Cameras

There are two kinds of cameras used in the ROV. The analog ones are using component signals and RCA connectors. The advantages of analog cameras are that they are simple and reliable. However, the problems of analog cameras are that the signal quality is bad via long tether and also each camera costs one pair of wires. Thus digital cameras, i.e. USB Webcams are used as all the signals are digital. The numbers of cameras can be freely increased as long as the tether bandwidth is enough. Also the image quality is much better in comparison with the analog ones.

f. On board microcomputer

A powerful computer is needed as a host so that the USB cameras can be driven and data can be packed and transmitted. Never the less, an intelligent operation system can be installed into this computer. The only data output connection is implemented by a twisted pair cable working at 10/100M IEEE802.3 LAN standard. The CPU used is Intel Atom D525 running at 1.8GHz and memories are 2G DDR3

RAM and 60G SSD. The power of the microcomputer is provided by a DC-ATX power-supply that uses 12V DC from the internal power supply module.

g. Active Cooler

Since there are many electronic devices inside the waterproof capsule, it is important to carefully consider the heat dissipation. Many devices are sensitive to the temperature. When the temperature is high, the MOSFETs may break down. Thus an active cooler is added. A semiconductor cooler pad is attached to the back aluminum pad so that the heat can be effectively transferred out of the waterproof capsule. For better performance, two aluminum heat-sinks are attached both outside the aluminum pad and the inner face of the cooler pad.

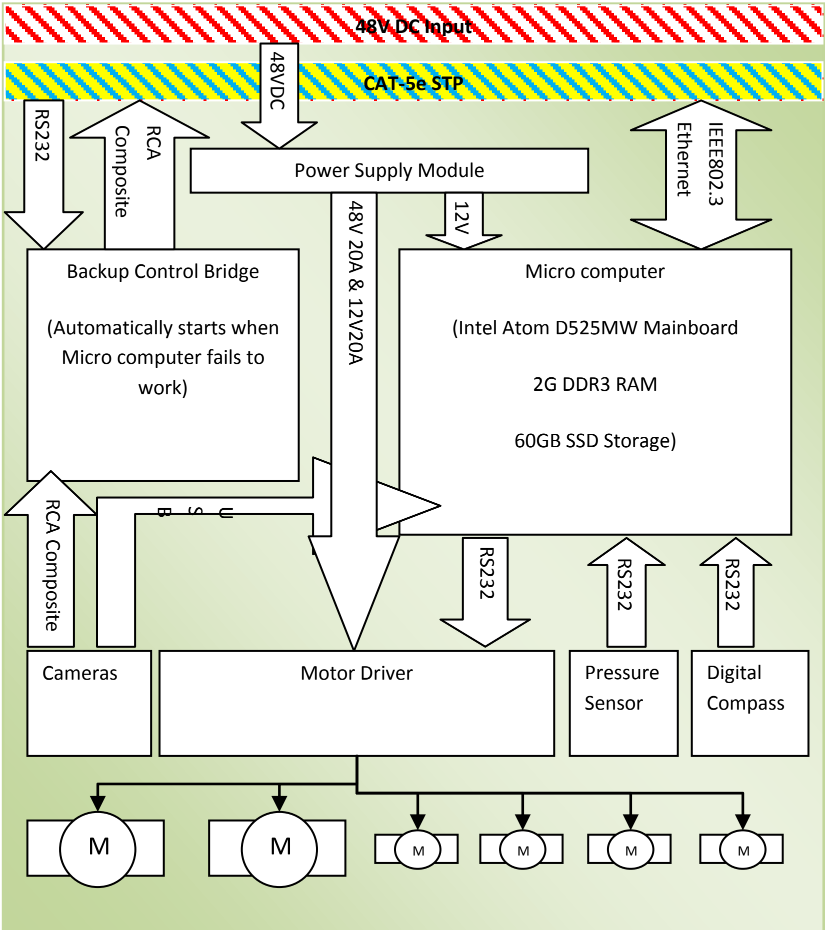
The voltage supply of the semiconductor cooler pad is 12V and the maximum power is 25W.

h. Tether

There are simply three wires for the tether. Two thick copper wires are used for power transmission, one is for 48V positive and the other is the ground. The cross-section area of the wires is 10 square millimeter. Thus the wires are able to transmit up to 40A current. The rest wire is a typical Shield Twisted Pair, i.e. a LAN cable. Inside the LAN cable, only 4 wires are used for IEEE802.3 10/100M transmission. Two of the rests are used to transmit RS-232 signals for backup control and two are used to transmit RCA component video signals for backup monitoring. The number of wires is eliminated to the least for better movement performance of the ROV.

3. Software and Control System

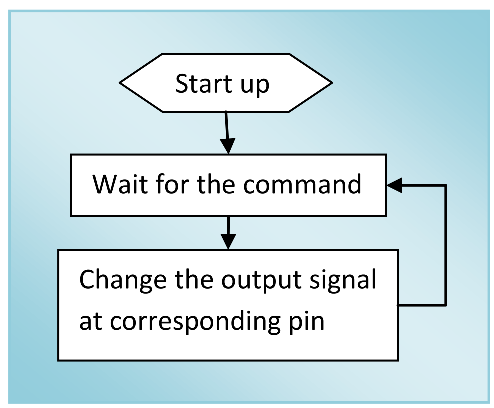
Though there are many devices can be used to control the ROV, it will be controlled by only one pilot using an XBOX360 game controller during the competition. On the shore there will be a laptop computer fetching data from the game controller and displaying the ROV camera video scream instantly on the screen. Other important data will be shown on the screen as well such as the immediate attitude of the ROV, the depth, warning information, etc. Thus the on-shore laptop computer communicates with the ROV via the LAN cable. There are two occasions. One is when the on board microcomputer works properly and all services are running. Then the two computers talk to each other directly. Otherwise the on-shore computer will talk to the mother board directly to perform operations.



As seen from the block diagram, under normal occasion, commands of RS-232 signals are transmitting from the micro computer to the driver boards. The protocol is straight forward. Any command send from computer to the driver consists of five bytes. The format is "$DXXX" where the letter "$" is an identifier that indicates it is a start of a command. The letter D indentifies the addressing device of the particular command. Since all the commands are transmitted on the same signal line, each driver board is only sensitive to the command addressing itself. The next three bytes are carrying information for the specified driver boards. For example, "$1050" is telling the driver board No.1 to give an output power of 50% clockwise running at the motor No.1. "$A110" is telling the lighting driver board to set front and side lights on and back lights off.

At the driver board side, the working flow of the microcontroller is quite simple. The programs are written in assembly and actually they are real-time and multi-task core systems.

Whenever the microcontroller starts up, a timer is set up for queries with constant intervals. It checks the preset conditions for different tasks, for example, the PWM generator counter or command buffer. Usually, it waits for the command and then changes the output value. Although it looks like sequence logic, it is not. It is implemented by real-time multitasks processing method. The advantage of this method is that the microcontroller becomes more stable and solid when exceptions occur. Even a severe error occurs the micro controller is still able to work because the error will be ignored and the rest of the tasks are done accordingly.



With the help of digital compass and the micro computer, the ROV can achieve advanced functionalities such as auto balancing and depth locking. The control system is simply a PID controller implemented by software inside the micro computer. This feature makes controlling much easier than ever. The pilot may turn on the semi-auto-pilot service and regardless of the positioning problems in order to focus on the operation itself.

Project Experience

a. Obstacle and Challenge

The biggest challenge for us is that our school does not provide funding for us at the beginning. As poor students, we could not purchase such a big amount of money. Some of our teammates even want to leave our team. But our team didn't give up. On one hand, we built a robot with limited resources and materials and using that robot, we get the qualification to international competition.

On the other hand, we tried our best to find funding. We tried three departments in our school and talked with them many times. After two month's hard work, we finally get financial support from our school.

b. Troubleshooting

Troubleshoot is carried on with the process of testing and debugging. The team was separated into two groups and worked together during the troubleshooting session. One group operated the vehicle, while the other one went through the operation status for problems, then the whole team held a meeting to brainstorm and put forward applicable solutions in the aspects of mechanism, material and circuit design to fix the existing troubles. Some troubles could be figured out individually, however, in most cases, they were closely correlated, which challenged us to have an overall horizon on this project. During these procedures, original designs were often replaced by new ones which could perform more effectively and stably.

Originally, the control for each motor is separated on the control panel. This system is able to control the robot moving correctly; nevertheless it is cumbersome and unstable. To solve this trouble, a command set was written on the MCU that each control rod represents a motion such as turning left or right and control several motors at the same time.

c. Personal Reflection

Jessica: After joining in this competition, I gradually learned the true meaning of team spirit. In a team, our teammates are happy together, sad together, work hard together, cheer up each other. I really enjoy the feeling of being in a united and warm team. It makes me strongly feel that I'm not alone and our teammates are all here with me.

Oliver: Gained quite a lot from this competition, knowledge learned from books was able to be applied to a real robotic product. Besides the technical practice, inter-personal ability as well as the team cooperation skill is greatly improved since we need to get sponsor from all around and unite the whole team to pursue a same goal- to win this competition!

Gus: This is the second year I joining this competition. I got a lot of lessons from last year's experience and now I am always being more careful and strict when designing and making the devices. Last year's experience also told me that failure is not something we should be afraid of, but something we should appreciate. I am now confident and I am now encouraged do everything better. This project not only taught me how to make an ROV, but also how to design a product and how to manage a team.

Haven: During the process of building our ROV, new ideas kept coming up to our minds driving us to perfect our design again and again. And some original designs were denied during tests due to their unsatisfactory practical performances. Whatever, through trial and error, we tried our best and I enjoy all the work done.

Robin: The true measure of success of software is its ability to serve the team as a tool. At the end of the day, friendship is my most valued treasure along the way.

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