INTEGRATE
Develop Your Mind

Integrate is an Egyptian company aiming to develop and advance the Robotics industry, spreading knowledge technology and team work abilities across the globe. We achieve our aim by hard work, building new bonds and most of all passion

Integrate teams simply **never** gives up…

BETA Technical Report

Beta Integrate Team, 2013

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Abstract

The following technical report describes the Remotely Operated Vehicle (ROV), Beta, which was designed and created by Beta Integrate Company. During the phase of construction, the team worked together creatively and efficiently to produce an ROV that can complete the designated tasks of this year's International ROV Competition. Beta team discovered ways to solve their problems, advance their ROV, and learn through their mistakes.

Beta was designed over a period of nine month to complete the mission specifications of the 2013 Marine Advanced Technology Education (MATE) competition. Designed to perform and complete this year's tasks with precision and flexibility.

This report includes detailed descriptions and diagrams of the ROV and its control system components; challenges we faced and overcame along the way; lessons we learned; a list of things we would like to improve on next year; skills gained through of the process and experiences we went through, a list of all those individuals and groups who helped us get here.

Beta Team

Design Criteria:

Body:

Material Choice:

We had different types of materials to choose from such as artilon, PVC, stainless steel (tubes and sheets) and aluminum. We choose the aluminum based on its ease of use, cutting, wide variety of assembling and modification. In addition, it has the ability to withstand corrosion for a very long period of time.

We choose 3 mm thick "L – shape" 3 x 3 cm aluminum rod which is tough satisfying extreme condition the ROV might face during its mission. Simply our ROV can take hits without having major damages to its body.

After cutting 50 cm (length) x 30 cm (width) x 20 cm (height) L shaped aluminum rods, we formed a rectangular shaped body. Thinking about motor positions we placed aluminum rods at 22° degrees at corners to place motors on them.

Stages of building Beta are shown (fig 1):

Fig 1

Buoyancy Principle:

Taking in consideration, that anything to float in water needs to undergo the buoyancy formula. Buoyancy is the phenomena given by Archimedes which says the body experiences the upward force when it is partially or complete immersed in liquid. Buoyant Force (fig 2) is given by the following formulas:

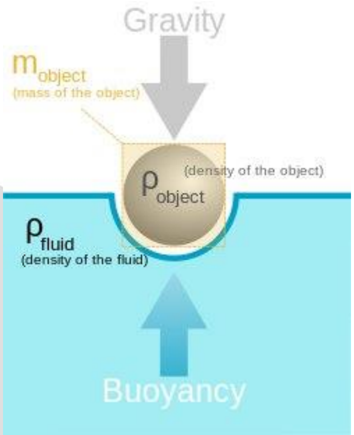


Fig 2: Buoyancy Formula

In terms of buoyant force:-

$$F_b = PA$$

Where (F_b: Buoyant force, P: Pressure, A: Area)

In terms of volume:-

$$F_b = \rho g V = \rho g h A$$

Where (F_b : Buoyant force , ρ : Density , g: Gravity , V : volume of immersed part from the body in the water , h : Height of the immersed part from the body in the water, A: area) *(1)

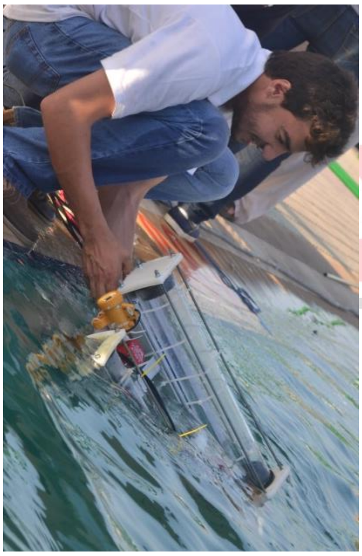


Fig 3

After learning how to adjust buoyancy to reach buoyant point of ROV, we used acrylic tubes as our main air chambers on both sides of the ROV and we fine-tuned the ROV's buoyancy by extra loads or extra variable tanks (water bottles) according to water variation. (Fig 3) shows our mentor Eng. Ashraf teaching us how the variable tanks work.

Propulsion system

1st phase: -

Motor Choice:

Our motor choice was based on insulation, performance, and power supply specifications "Voltage and current". After going through several filtering processes through a great varieties of motors (some non-isolated motors which needed to be insulated before use, others already isolated but don't meet the power specifications either high amp drawn or requires higher voltage which will complicate our circuits by adding an amplification circuit). We have settled to use an 1100 GPH (Gallon per Hour) bilge pump (12v 5A) which we altered by cutting its front part (Fig 4) then removing its impeller (Fig 5). (Now we were ready to proceed to the next phase).

Fig 4: Omar while removing the front part of the bilge pump.

Fig 5: Bilge pump after removing impeller.

2nd phase: -

Propellers choice:

This phase was one of the hardest phases through the thrust phases because most of the team didn't have experience in this phase so we started by searching the internet for assistance we found some programs that can assist in designing a propellers, but we faced a hard time putting the design to reality due to lake of fabricating abilities in our country so we formed that fabricating will consume a lot of our budget. So we bought several propellers with different sizes and blade numbers and tried them till we settled on our propeller shown in (fig 6) and casted copies of it to reduce our budget.

Fig 6

NOTE: *casting was not that efficient but we had sacrifices due to financial issues (a CNCed propeller would have been much efficient and lighter which will affect the thrust power).*

3rd phase: -

Kort Nozzle (Ducted Propeller):

A ducted propeller, also known as a Kort nozzle, is a propeller fitted with a non-rotating nozzle. It is used to improve the efficiency of the propeller and is especially used on heavily loaded propellers or propellers with limited diameter *(2). The Kort nozzle is a shrouded propeller assembly for ROV propulsion as shown in (fig 8).

4th phase: -

Thruster Assembly:

Fig 7: Coupling and Propeller

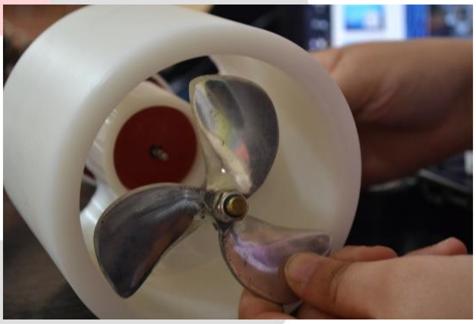


Fig 8: Setting up propeller with coupling with motor.

Fig 9: Propeller fixed with motor using lock nuts.

Fig 10: Motor while working with propeller mounted.

Motor Configuration

We tried more than configuration before settling on our choice. A sample of a configuration we tested (fig 11).

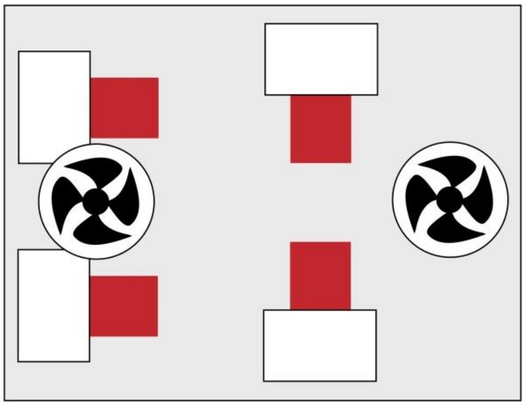


Fig 11: First Motor Configuration

After testing we fixed our motors as shown in (fig 12) if ROV is able to move in all possible directions. So we can dive, float, go forwards, backwards, to the right, to the left and rotate. We can use 2 or 4 motors for each direction to increase speed (excluding diving and floating functions; we can only use 2 motors).

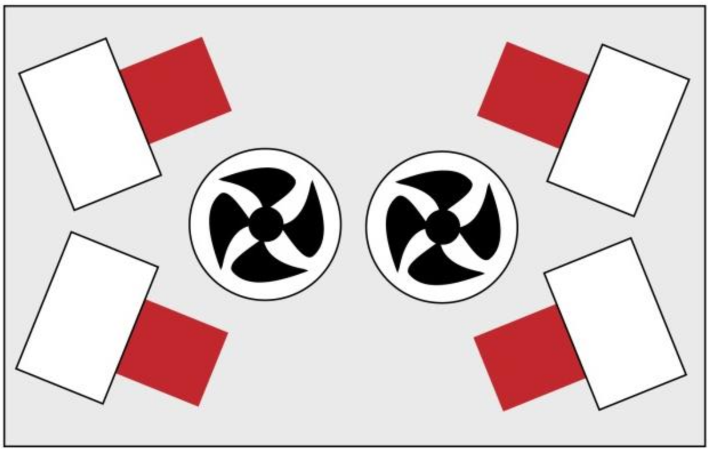


Fig 12: Beta Motor Configuration.

Electronics:

Electrical schematic:

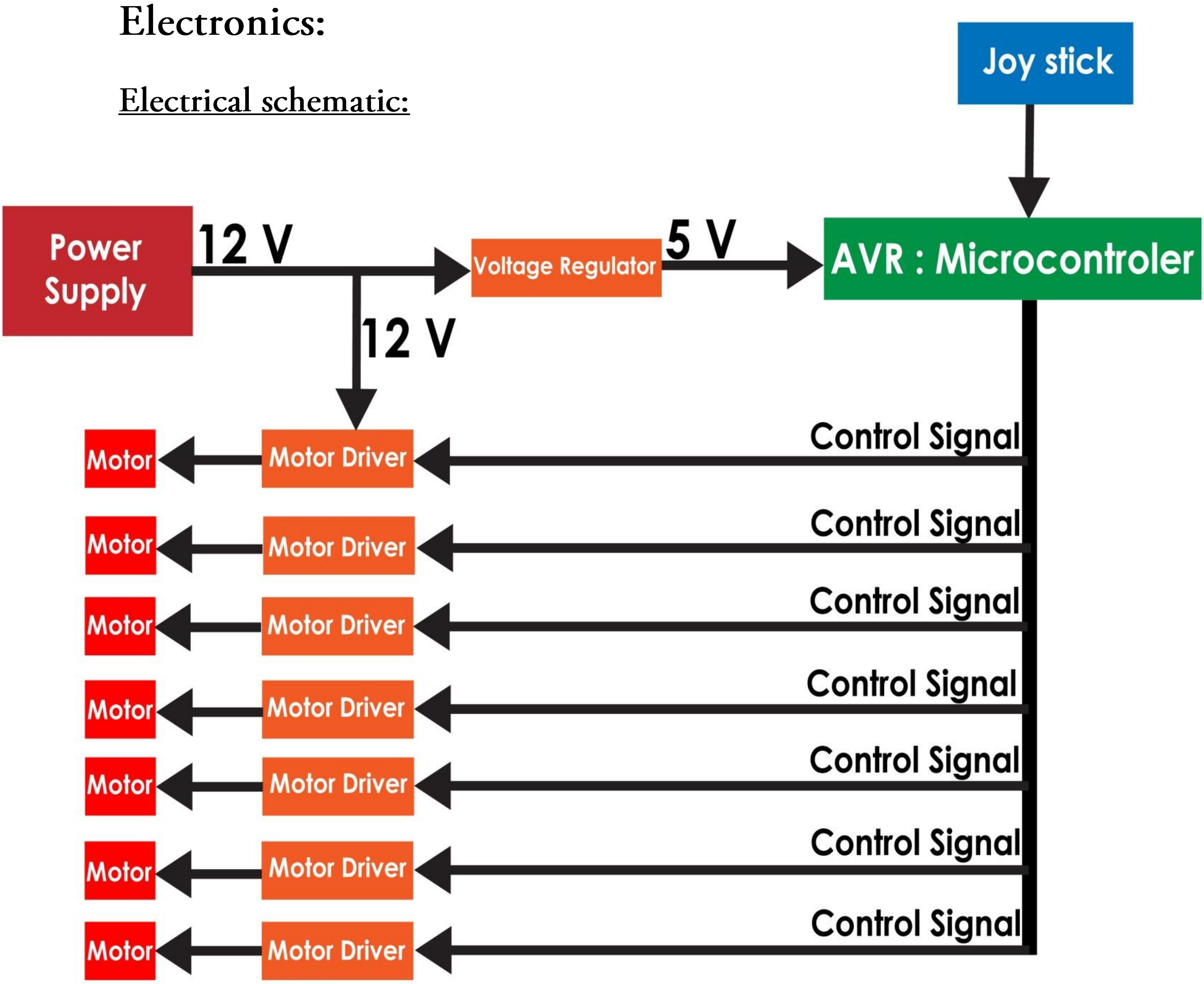
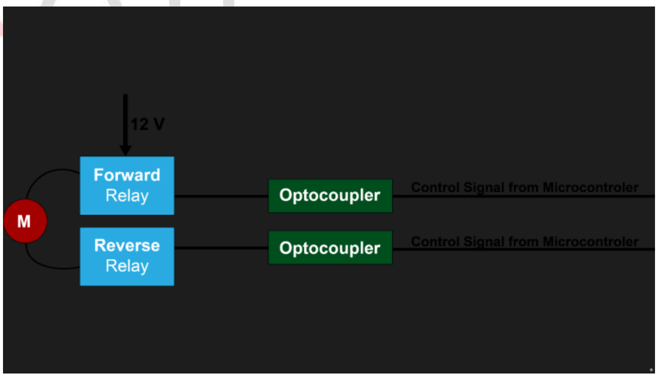


Fig 13: Circuit block diagram.

In (fig 13), Power supply provides 12 volts to the whole circuit. The microcontroller needs 5 volts to run, thus the circuit has a voltage regulator “7805” to provide that with capacitors for smoothing the voltage in case of any sudden voltage change. The AVR chip senses the joy stick for any input impulses referring to Fig 14 after processing it. Then sends the corresponding control signal to the motor driver to activate specified motor(s).



(Fig13’: Motor driver in details)

Control System:

Our team spent a great deal of time to make our control system easy and simple; to offer wide range of easy maneuverability in order to complete our mission tasks as efficiently as possible. We decided to implement digitally based control system. This control system allows the ROV's operators (pilots) to interface easily with the robot through a familiar joystick "PlayStation joystick".

After trying multiple types of controllers, we settled for one and started modifying it to match requirements needed. For a start we rewired it according to buttons needed; each button acted as a switch which triggers an input pulse in to the AVR chip (AT Mega 16), by doing that it activates the corresponding opto-couplers switching the desired relays to N/C (normally closed) activating the motors in a certain direction according to programmed code. (Explained clearly in Programming page 11)

Each button in the controller is designed now to control a single movement by activating 2 up to 4 motors. Fig 14 illustrates connection between controller and motors.

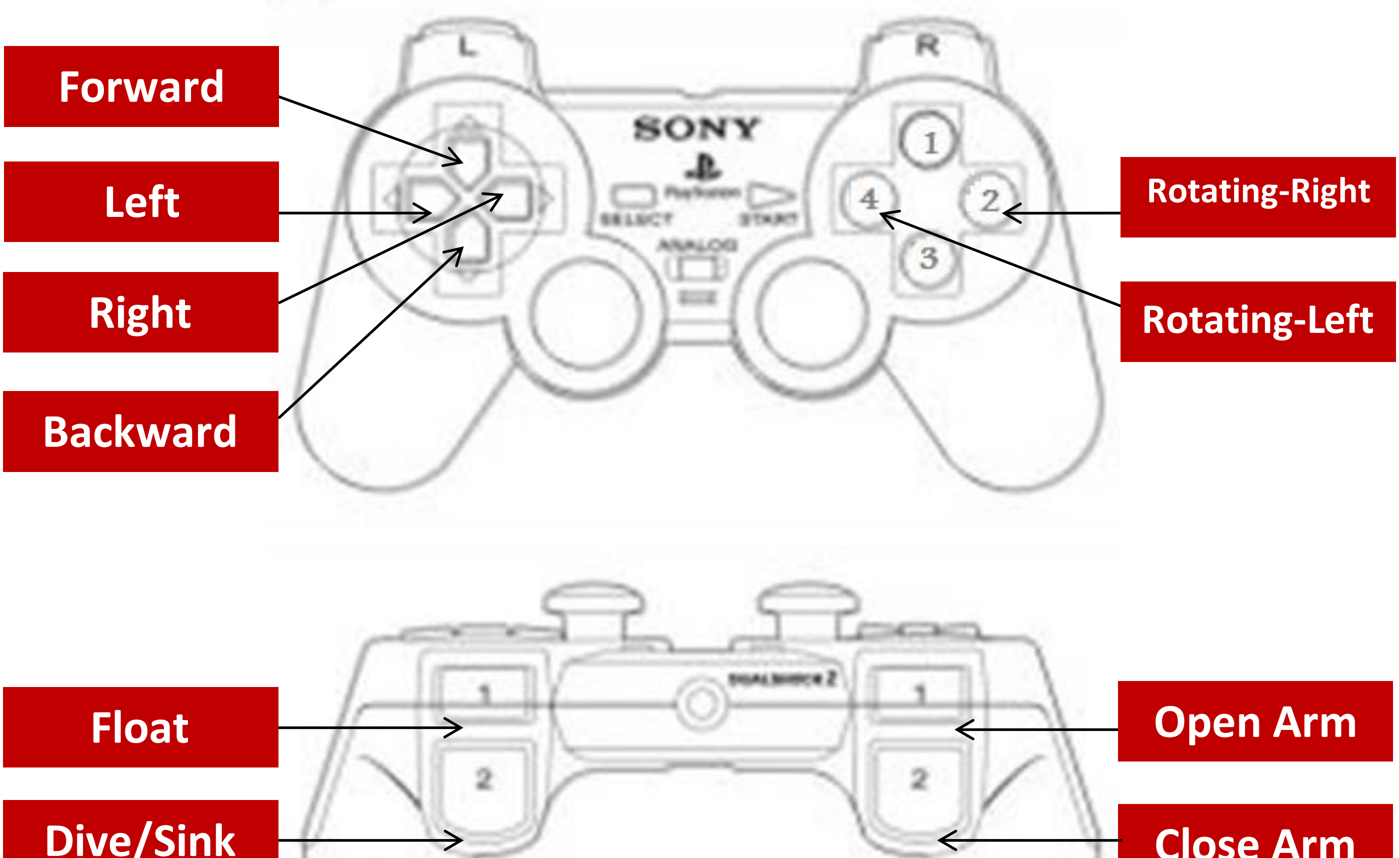


Fig 14: Controller

Programming:

The AVR chip acts as an interface between a PlayStation joystick used by the pilot and relay connected to a motor that controls the ROV's motion. The computer's program was written on **CodeVision AVR** (shown on page 12) in Embedded C Language. As the pilot presses a button on the controller, this input signal is checked through the program to figure out which motor to activate.

First we started our software design by deciding the input and output pins on AVR (as shown Fig 15). The input pins were all of port B and 6 pins from port A, while the output pins were all of port D and 6 pins from port C. while the pins which were not used were configured as output in order to avoid the noise generated as magnetic field from the thruster motor and the coil of the relay. As the AVR has an over noise reset. These pins were (A.6, A.7, C.6 and C.7). Then we wrote the buttons of the joystick, considered as the input pins while the output pins, we wrote the direction of the motor forward and reverse. After that, we started writing our code to suit the function we desired.

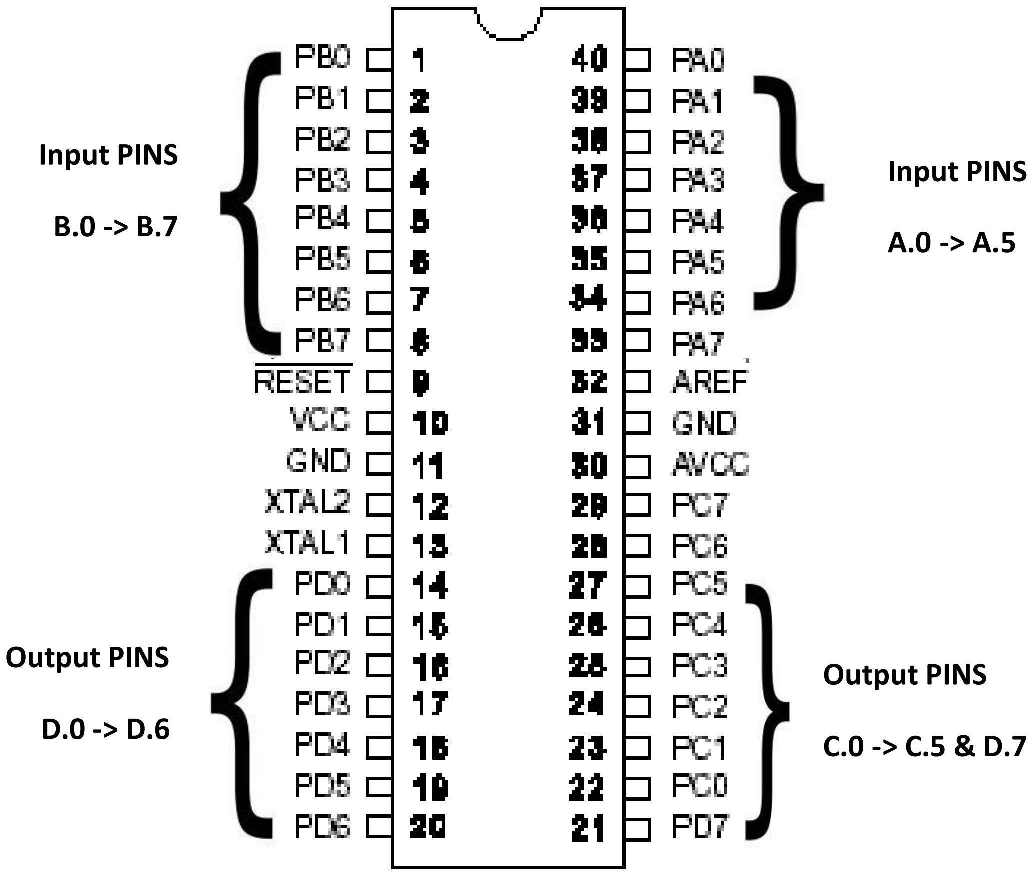


Fig 15: AT Mega 16.

Code programmed to AT Mega 16.

```
        while(1)
        {
        if(PINA.0==0)
        {
            PORTD.0=1;
            PORTD.2=1;
        }
        if(PINA.1==0)
        {   PORTD.4=1;
            PORTD.6=1;
        }
        if(PINA.2==0)
        {
            PORTD.0=1;
            PORTD.4=1;
        }
        if(PINA.3==0)
        {
            PORTD.2=1;
            PORTD.6=1;
        }
        if(PINB.2==0)
        {
            PORTC.0=1;
            PORTC.2=1;
        }
        if(PINB.3==0)
        {
            PORTC.1=1;
            PORTC.3=1;
        }
        if(PINB.5==0)
        {
            PORTD.6=1;
            PORTD.0=1;
        }
        if(PINB.7==0)
        {
            PORTD.2=1;
            PORTD.4=1;
        }
        if(PINB.0==0)
        {
            PORTC.4=1;
        }
        if(PINB.1==0)
        {
            PORTC.5=1;
        }
        PORTC=0x00;
        PORTD=0x00;

      }

  }
```

Fig16: Code

Backup System:

We've made a backup system (fig 17) in case anything happened to our original control system. This backup system consists of relays and a joystick. Every button in the joy stick is connected directly to the relays coil according to desired function and every relay is connected to one of the motors to operate it clockwise or anticlockwise. Every motor is connected to two relays one to operate it in the clockwise direction and one to operate it in the anticlockwise direction.

Fig 17: Backup system circuit board.

ROV gear onboard:

Gripper:

We made the ROV with symmetric design so it can be filed on forward and reverse easily, allowing us to use arm with great functionality and simple pilot interface. First our arm has a mechanical and electrical mechanism. We used a bolt in our arm. So when the motor is rotates clock or anti-clock wise, the arm gripes or releases, shape on (fig18). Its design made it useful to hold obstacles tightly. In addition we made sure to design the gripper able to hold the largest and smallest diameter in mission playground. We used artilon in building that arm for its turgid material and easy shaping. In addition, we made a backup arm, it is a fixed one which can apply tasks that don't need motor actuation.

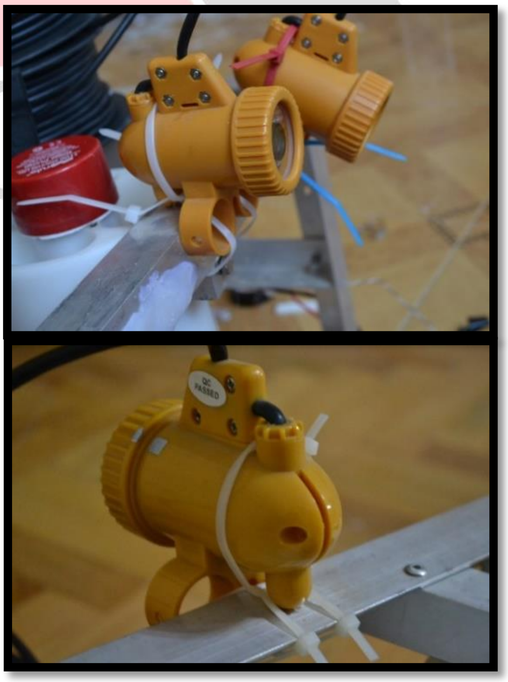
Fig 18: Arm.

Camera:

Our cameras are simple and effective method of visual navigation. We didn't put in consideration isolating the camera as it is already waterproof. The most important aspect in using the camera is positioning it in right place. Our camera is attached to the front of our ROV for tools in full view. Also another is placed at the back of body to allow motion in reverse and prevent hitting obstacle while moving. Lastly the third one was placed to view arm; its purpose is to allow pilot for accurate implementation of missions. All positions shown in (fig 19).

Specifications
Image sensor: 1/4 inch color Sony CCD
TV System: PAL/NTSC optional
Effective Pixels: 628x582/628x512
Sensing Area(mm):3.6x2.7
TV lines: 420TVL
Horizontal Sync.Frequency(KHZ): 15.625/15.734
Vertical Sync.Frequency: 50/60
Video Output: 75Ohm
S/N ratio: Betterthan45DB
Gamma Consumption: 0.45
Lens: 3.6mm
Lens Angle(Deg): 92
Current Consumtion (MA): 500MA
Power Supply (DCV): 12V
Leds: 24 LEDs
MinimumIllumination: 0.8Lux/F1.2
Underwater visual distance(m): 0.5~1.5m
IP rating: 4Kg/cm2
Operating Temperature(Deg): -20~+75 (RH95% Max.)
Storage Temperature (Deg.): -40~+85(RH95%Max.)

Fig19: Camera positions.



Front and Gripper View

Back view

Temperature Sensor:

This sealed digital temperature probe lets you precisely measure temperatures in wet environments with a simple 1-Wire interface (fig20)

The DS18B20 provides -55°C to+125°C range and is accurate to ±0.5°C over the range of -10°C to +85°C.So that only one wire to transmit the temperature in 9-bit to 12-bit Celsius temperature measurements packets. Each packet contains the temperature separated to two parts LSB (Least Significant Byte) and MSB (Most Significant Byte) as shown in (fig 21).

Fig 20: DS18B20 "Temperature Sensor - Waterproof"

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
MS BYTE	S	S	S	S	S	2^6	2^5	2^4

S = SIGN

Fig 21: Temperature Measurements packets

Our temprature sensor needs some kind of processing to convert the packets at this shape to readable data for human (analog data). This processing technique implemented on AVR Microcontroller chip. This AVR recieves the packets from the sensor and convert this zeros and ones to readble data , The AVR displays the reading of the sensor on Alphanumeric LCD every 90 seconds as shown in (fig22) .

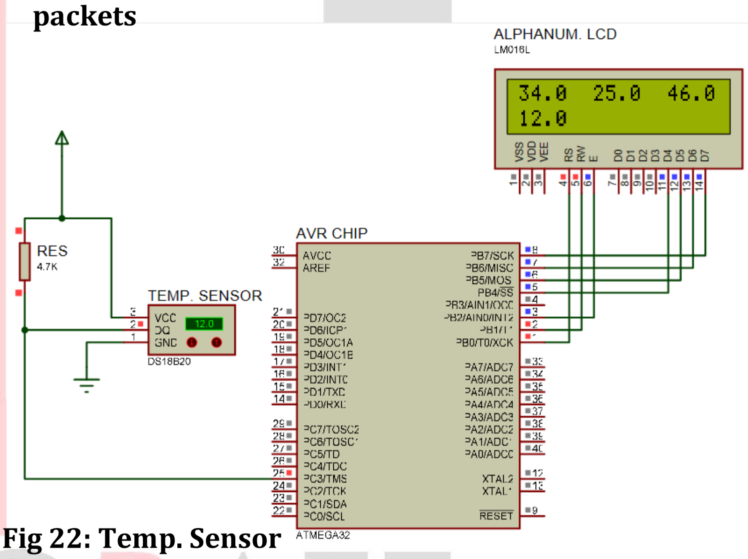


Fig 22: Temp. Sensor connection

After connecting this circuit, we started writing our code to suit the function we desired.

```
while(devices>1)
      {
          temp=ds18b20_temperature(0);
          if (temp>1000){
             temp=4096-temp;
             temp=-temp;
          }
          sprintf(lcd_buffer,"%i.%u  ",temp,temp%1);
          if(count==3){
           lcd_gotoxy(0,1);
          }

          lcd_puts(lcd_buffer);
          delay_s(90);
          count++;
      };
}
```

Safety:

Safety was the number one priority throughout our nine month training. We developed that through many procedures.

Safety Gear:

Our Company was equipped with the following:

- Safety glasses
- Acid plastic protective gloves
- Helmet
- Safety shoes
- 1st aided kits (fig 23)
- Fire extinguishers
- No loose clothes allowed during work

Fig 23: First Aid Kit

Mechanical safety:

- Smooth edges
- Kurt Nozzle We added kort nozzles to the motors (fig24) so that the propeller doesn't get attached to anything while in water; if it got attached to an obstacle may cause huge damage on motor and surrounding.
- Safety warning signs.
- Lock nuts.

Fig 24: Kort Nozzle protecting motor and propeller.

Electrical Safety:

- Safety fuses 25 Amp.
- No lose wires present
- Shielded control wire
- Protective coating on all PCB (in case of leakage or control box crack as an insulation extra layer).
- Placing electric circuits in acrylic tubes

Key point was to seal the acrylic tubes: Here is how we isolated it: To make sure that water doesn't enter these tubes, we closed them with rubber stopper (Fig 25). After testing rubber underwater, the pressure cause leaking of a few drops of water; so for further protection we assembled two 10-mm thick artilon blocks to sandwich rubber stoppers and acrylic tubes. (Fig26)

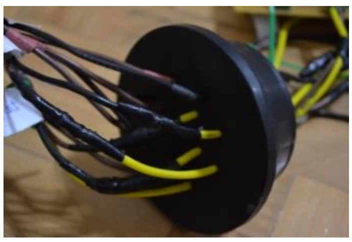


Fig 25: Passing electrical cables through rubber stopper.

Fig 26: Acrylic tube containing circuits

After further tests the rubber stopper system did not work as expected even with the artilon blocks so we changed the stoppers entirely. We manufactured a full artilon stopper with rubber O-rings forming three stage water insulation and wires passing through glands (fig 27). Our new system was proved efficient after testing it 4bar in pressure chamber.

Fig 27: Artilon stopper with O-rings and glands.

Challenges Faced and Lessons Learned

During the building and testing process of our team's ROV, we learned a lot about underwater physics. Our team based our design upon neutral buoyancy. Although this became an additional challenge, our team gained more knowledge of physics underwater while trying to overcome this challenge. As we made several attempts to modify, adjust and test our ROV, we observed how changes in design changed the performance of our ROV. As we tested the ROV more, we began to interpret our observations and begin to change some aspects in our design. Also some of our time was wasted in repeating circuit boards that were misused the first time, but we learned from our mistakes and tried hard to perfect it.

Another challenge we overcame was our observations during testing our ROV controls. When attempting to aim for the target, we saw how long it took for the ROV to execute a maneuver and how long it took to stop. Some of the members had never driven anything like it before; it was easy for them to lose control over the ROV at first. But after months of training we finally got the hang of it and could control it easier; thus completing desired missions.

The ultimatum challenge we faced was water leaking through the rubber stoppers to the circuit boards, causing damage. We put our heads together and came up with a solution that was actually better that the rubber stoppers, artilon blocks to isolate acrylic tubes which contain our circuit boards. Further explanation on this matter is explained on page 14.

Another lesson learned was how to manage our time, resources and how to function as a team. Teamwork was essential in this project, without everyone's contributions we would not have succeeded this far.

Skills acquired:

Fig 28

Designing and building a ROV from start to finish requires hard work, determination and teamwork. The most rewarding part of this experience is seeing the project from the initial planning stages to the end product. The sense of pride and accomplishment that comes with completing such a task is very satisfying. Looking back it is hard to believe that we did all of this ourselves, as a team. Individual strengths were recognized and members took leadership roles in each technical area.

We gained technical skills such as doing basic mechanics calculations of vector forces for motor placements for highest efficiency output, understanding and building electrical schematics, embedded C programming for micro-controller (AVR AT Mega 16), implementing current calculations into circuit designing, knowledge of basic mechanics (fig28), electrical and plumbing principles, researching topics and summarizing them and finally technical writing by writing this report.

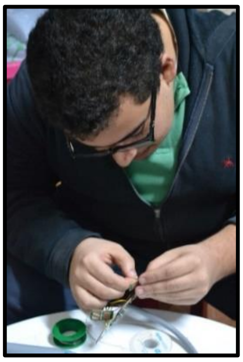


Fig 29

Fig 30

Also we acquired practical skills: wielding tools properly, printing circuit schematics onto boards, fitting, drilling and soldering components onto printed circuit boards (PCBs), testing and handling circuits (fig29, 30).

Reflections:

To get all this work done we had to work and function as a team. We were strangers to each other at first but united under our passion for innovation, we worked with new acquaintances easily (fig33), and we shortly became not only friends but a family (fig 32). By working as a part of a team made us learn and understand making decisions (fig31) and how it would affect the rest of the members. Through group cohesiveness, the group's members gained a sense of belonging, respect and trust, which really boosted our progress and performance dramatically. A group is not dependent on the skills of one person but on the whole group, as we all are one. In a group it is possible for an individual to take on different roles. Each role will reflect how individual skills and responsibilities change with time. Presentation skills were gained as we presented our company to magazines and professors many times. Together Everyone Achieves More (TEAM) was our motto, and that's what helped us to get this far.

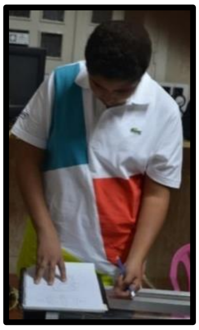


Fig 31

Fig 32

Fig 33

Future Improvements

Our team has several ideas that we plan to implement in the future to improve upon the design, functionality and ease of use. One priority is to create more tools to accomplish the tasks at hand in the 2014 MATE International Competition.

Another improvement our team will have to make will be to increase publicity in the community. A lot of people in Alexandria still don't know what an ROV is. Next year, we will have a campaign early in the year to acknowledge citizens with the competition. Also, time management is an important aspect, as we are still learning, skills can always be improved. During the end of the year, all team members had exams and we had to make final touch ups on the ROV at the same time.

Budget

Item	Price ($)	Number needed	Total cost ($)
Motor	47	7	329
Coupling	0.66	10	6.6
Propellers	0.66	10	6.6
Kort Nozzle	80	3	240
Camera	120	3	360
Aluminium	3.7/meter	18 meters	66.6
Bolts & Lock Nuts			80
Artilon			126.6
Electronic Components & PCBs			500.6
Acrylic tubes	11.7	2	23.4
Temperature Sensor	14	1	14
Old PlayStation joystick	8.6	1	8.6
Used PlayStation joystick	3.4	1	3.4
TOTAL			1765.4$

Additional Cost:

Mechanical Tools	8.5 $
PVC for playground	10.6 $
Plastics Sheets for playground	2.6 $
TOTAL	21.7$

Grand Total -- **1787.1 $**

References

1. http://formulas.tutorvista.com/physics/buoyancy-formula.html
2. http://books.google.com.eg/books?id=rNoDAAAAMBAJ&pg=PA369&dq=Popular+Science+1935+plane+%22Popular+Mechanics%22&hl=en&ei=r81ETsS3KI3isQLY3dX5BQ&sa=X&oi=book_result&ct=result&redir_esc=y#v=onepage&q&f=true

Acknowledgements

Any project of this scope requires the dedicated efforts of many people. While it is not possible to identify them all by name, we would like to express our appreciation to the following for their particularly significant contributions.

Without question, our mentors Eng. Hany George, Eng. Mahmoud El Said, and Eng. Ashraf Abd El Aziz deserve the highest commendation for their selfless reassurance and limitless patience. Without their help, which included donating several hours of their precious time to provide us with technical assistance, the work necessary to complete this project would have been impossible.

We would also like extend our thanks to Eng. Mohamed ElHalwagy who helped us in designing the poster. Moreover, we are also grateful for Eng. Ahmed Zaghloul for creating a 3D model in solid works. Without forgetting Eng. Ahmed Ramy who helped us testing our gripper. Also thank Dr. Ehab Abdallah who has been very helpful.

We would like to acknowledge the vital contributions of our training center INTEGRATE; for its commitment in supporting this project. Becoming our second home; it developed in each and every one of us the sense of affiliation to a place.

Special thanks and gratitude are to be addressed to our parents and our media sponsors Hashtags, Kelmetna and TeenStuff magazines and other newspapers such as **Al-Masry Al-Youm** for their support throughout the different phases of this project.

Our most valuable thanks to **MATE** for creating such a great event collecting teams from all across the world and another thank you for our national organisers **Hadath** and the **Arab Academy for Science and Tech. (AAST)** they were most helpful since our registration started till the end of the regional competition and after.

Also a special thank u to each and every one whom supported us by liking and sharing our Facebook page (https://www.facebook.com/integratebetateam); helping us fulfil our goal.