SAUDI AQUATICE

University of Hail

Saudi ROV Team

Hail, Saudi arabia

Technical RepoRT: Saudi RoV

Team member

Saudi ROV TEAM MEMBERS		
Name	**Major**	**Role**
ALSHAMMARI, NADER	Mechanical Engineering	Team Captain & Co-Pilot Advertising, Logistic support, Procurement
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AL WAHEED, AMMAR	Mechanical Engineering	Pilot Mechanical Design& Mission Management
ALSHAMMARI, ABDULRAHMAN	Mechanical Engineering	Co-Pilot ROV modeling and Tasks
ALHARBI, SATTAM	Mechanical Engineering	ROV modeling, SolidWorks and Report writing
ALJOHANI, MOHAMMED	Mechanical Engineering	Electromechanical measurements & Budget

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MOHAMED ELASHMAWY	Mechanical Engineering	Leadership Mechanical Design, ROV modeling and SolidWorks
MOHAMMAD ALNAIS	Mechanical Engineering	Research and Development
ISAM ELBADAWI	Industrial Engineering	Planning, Training and report writing
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Acknowledgment

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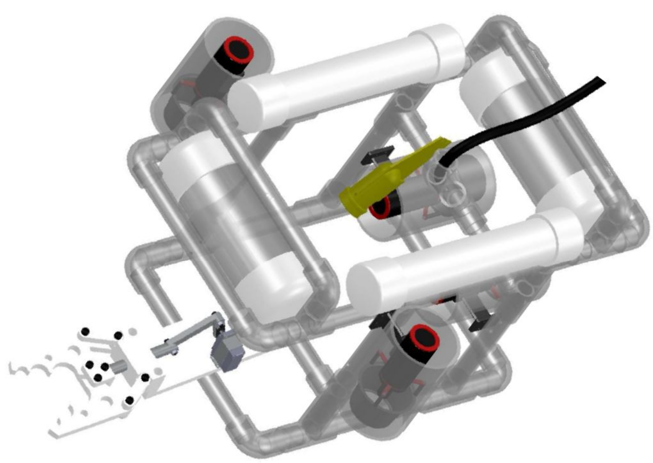
Saudi ROV appreciated too much the support of Engineer Shaban Badawi for his great help and support facilitating ROV materials shipments from Washington DC to UoH, and Mr. Bandar Ahammari From Saudi Telecommunication (STC) Company who provided Data wiring and BDF,s.



AbstrAct

Remotely operated underwater vehicles (ROVs) are remote controlled underwater robots driven by an individual on the surface. These robots are tethered by a series of wires that send signals between the operator and the ROV. All ROVs are equipped with a video camera, propulsion system, and lights. The purpose of this project is to design and build a remotely operated underwater vehicle (ROV) to participate in the Marine Advanced Technological Education (MATE) ROV competition. This competition is divided into three categories, Scout, Ranger, and Explorer. Saudi ROV entered into the “Explorer” category, which is the most advanced.

A team composed of five members, known as ‘Saudi ROV,’ have constructed and designed an adaptable, intuitively controlled ROV. All mechanical, electrical, and programming control systems and subsystems were created to perform a specific set of tasks published by the MATE.

Saudi ROV acts as a versatile platform, with a frame constructed of adaptable transparent PVC channel. A waterproof pressure vessel constructed of PVC houses electronic controls, and provides additional structural support for the frame. Four (0-50) volt thrusters provide propulsion. These, along with a 50 foot tether, terminate at the enclosure housing using wet mutable connectors. Neutral buoyancy and stability are achieved by the addition of two water sealed 2-inch PVC pipes as floaters. Two cameras positioned strategically on the ROV encompass all mission-specific manipulations in their field of view. Manipulations and propulsion systems are controlled by a student-designed electronic system, which utilizes Parallex-PX 3820 microcontroller.

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Introduction

Engineering Research Group (ERG) at University of Hail (UoH) has designed and assembled Saudi ROV *(**R**emotely **O**perated **V**ehicles)* to accomplish the tasks set forth by the 2013 Marine Advanced Technology Education (MATE) International ROV Competition.

After receiving the ROV Fund from the university students affairs for discovery and Research, the company recognized that the design process would require both cooperation and flexibility among different departments. This necessity was caused in ROV parts availability and uncertainty, which meant that no definitive plans could be immediately made for the purchase of certain components.

The team consists of four mechanical engineering design students and one electrical engineering student. The design student's primary responsibilities include designing and building the structural components, dealing with waterproofing and sealing, determining the amount of buoyancy required, and designing and building the electrical circuit for the Saudi ROV Structure as well as gripper. The electrical student took care of the electrical systems, controls, sensors, video, and tuning. Saudi ROV team meets to discuss the details of the project at least once every week. The tasks were delegated to the team members based on their individual strengths and interests.

Motivation

University of Hail has been involved in many design projects, but not under water project as Remotely Operated Underwater Vehicles. With that in mind, Saudi ROV team is proud to be the first team in the Arabic Gulf to represent KSA to be the first to take on the challenge and create a working final prototype by May 2013.

Moving from ground to underwater design is a humongous challenge that we decided to handle and convert as an opportunity for success.

Fig. 1: Team Members

Safety featureS

Safety was an important consideration for the company throughout the design and building process.

Several safety features incorporated into the design of the Saudi ROV where all thrusters are protected by Transparent PVC guards and ducts as an enclosure, Fig. 2 and warning labels are placed near any moving parts. Saudi ROV has several safety features to allow it to shut down in case of signal or power loss. Also all electrical connection protected with fuse system. Both thruster and servo speed controller are designed to buzz continuous peep reporting the reception of the control signals. Figure 2 shows the wire sealing with the enclosure concept.

Fig. 2: Wire sealing

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Saudi ROV Budget

The following is a summary of the project expenses due to first time participation in MATE ROV competition. While the company has created a detailed budget sheet, Table 1, for the sake of space in this report it has been condensed to a price for each broad category.

Table 1: Itemized Saudi ROV budget sheet

Item	Cost ($, US Dollars)
Competition fees	$100
Saudi ROV Uniform	$325
Advertising	$ 420
Books	$ 400
Thrusters	$2860
Controllers	$840
Joystick	$480
PVC Pipes and fittings	$580
Tether	$100
cameras	$110
Power supply	$650
Manipulator	$670
Logistic costs	$1000
Cables and electronic items	$500
Accessories	$400
Shipping (express overseas cost)	$2155
Flux Density sensor	$1000
data acquisition system	$1000
TOTAL	**$13560**

Design Rationale

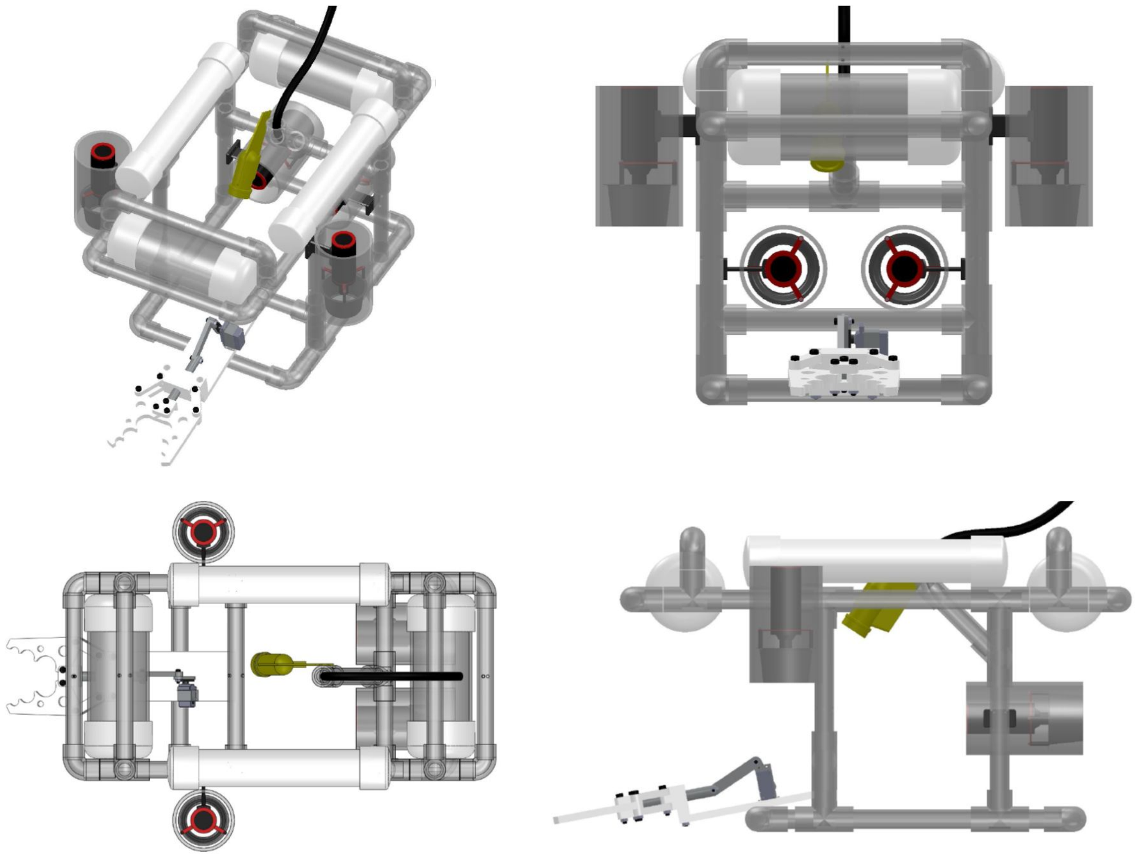


Fig.3: SolidWorks 3D-CAD design for the Saudi ROV

Since it is the first time for our company to participate in MATE competition we decided to benchmark previous ROV participants and companies. Also, because of the limited parts and material suppliers at KSA and Hail in specific we ordered a significant number of ROV parts globally especially USA.

Frame Assembly

The structural support for the ROV consists of transparent PVC pipes. Recognizing that the channel was easily adapted to support system change, the company designed the frame to promote versatility for every other vehicle component. The frame measures 33X68X32 cm in addition to 15 cm from each of the width for the vertical thruster's enclosures. The company considers this design to be a successful example of simple ingenuity, Fig. 3.

Manipulator

Saudi ROV manipulator was designed and manufactured inside UoH engineering workshop with Nylon materials known as Polyamide-66. The manipulator was built for function, with the capability to grasp large, heavy objects. Linear action is provided by a two-way servo, which is controlled by a 5-volt power supply. Also, the angle motion of the servo is turned into horizontal motion by a linkage system illustrated in Fig. 4. A second linkage, mounted to the front of the ROV, directs the gripper to open in parallel is mounted to the front of the ROV. The Manipulator is fixed to the front of the mission sled within the view of the forward-facing camera. The manipulator is attached to the mission sled using a simple receiver type hitch.

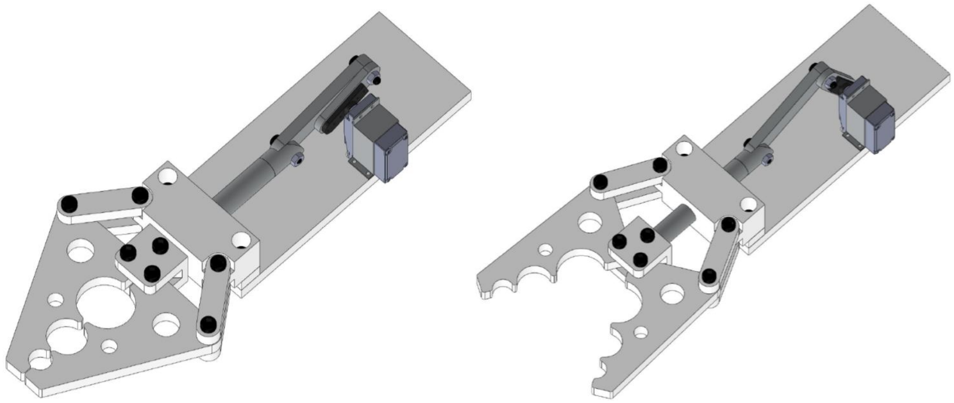


Fig. 4: SolidWorks 3D CAD design for the manipulator

Thrusters

We used four 400HFS- L Hi-Flow thruster in Saudi ROV, Fig. 5. Each thruster is 15.87 cm long and Produces 66.5 N of thrust. Two horizontal and two vertical thrusters were used. The horizontal two thrusters were used for forward and reverse motion and to facilitate 360^{o} vertical axial rotation through speed control of both thrusters. The third and fourth thruster used for vertical rotation, balancing, diving and floating.

Fig. 5: High flow thruster, 400HFS- L Hi-Flow

Camera

There are two cameras on Saudi ROV. First one was wide angle car camera modified and under water sealed by a hard past. The camera was tested before located above the arm which can help to complete the task. And the other one was fish underwater camera of readymade sealed for under water fishing task. Second camera was located at the center of vehicle which gives us other angle to see path. These cameras were chosen for their low weight, small size, and wide viewing angle and of course for their low price. Figure 6 shows the second camera view in the middle of the ROV.

Motors and Servos, Water protected Servo

8Fig. 6: BLS Brushless Servo Motor

The design of Saudi ROV‘s arm is mainly based on the digital brushless servo BLS352. This servo is selected in our application thanks to its Hi-Torque. It is an ideal device for use as a steering servo for 1/8 scale buggies. The BLS352 operates smoother and faster than brushed motors which ensure the high efficiency of the arm when performing the required tasks. A main modification has been made on the mechanical structure of the servo to reinforce its propriety of water protect. AS implemented Saudi ROV team exploits the BLS352 as a water proof servo device.

High Flow 400HFS-L-L" brushless Thruster Technical Specifications

"High Flow" AUV / UROV 400HFS-L thrusters where designed to be extremely powerful and customizable for any number of our customers unique UROV /ROV requirements. No other thruster on the market has the programmable flexibility to set specific operating parameters for different environmental conditions than the "High Flow" series. Machined from top of the line materials the Hi-Flow400HFS-L thrusters are engineered for powerful thrust capability in a small package.

Motor Specifications

- Motor Type – High efficiency brushless
- Weight – 185g. (6.5oz)
- Max Power – 400W
- Gear Ratio – 4.28:1
- Shaft Diameter – 5.0mm (.1969")
- Maximum Case Temperature – 100C (212F)
- Operating Voltage – 12 to 50 volts
- Operates in forward and reverse thrust

Connector Specifications

- Depth Rating – 300 ft.
- 3 wire

Thruster Housing / End Caps

- T- 6 Aluminum

Thruster Seal

- Motor - Flexible, polyurethane encapsulating compound
- Shaft Seal – Fluoroloy Lip Seal followed by encapsulating grease gallery

Thruster Weight

- Weight in air - 1 pound (.453kg)
- Weight in Water – 9 ounces (255 grams)

Thruster Length

- 6.25” (15.87cm)

Finish

- Black / Red Type II Hard Anodized Finish

Propeller

- Size – 2.36”” (60mm) - 4 blade
- Material – Solid Brass
- Propeller Adapter – Machined aluminum / Anodized Type II Black

Kort Nozzle Adaptor

- Material – .090 Aluminum
- Offset - 120 degrees

Thrust Rating

- 15 pounds + (6.79kg)
- 12 Volts – 8 pounds of thrust max
- 24 Volts – 15 pounds of thrust max
- 50 Volts - 15 pounds of thrust max

Buoyancy

Elements balance the vehicle pre calculated in SolidWorks environment. Their geometry and location were chosen for the baseline condition of neutral buoyancy of entire ROV and the absence of hydrostatic moments of heel and trim. Adjusting was carried out using balancing weights. To achieve stable balancing the company paid extra attention on how to accomplish the tasks and maintain the balancing of the vehicle. Also, putting the thrusters outside the frame which give us space allowed ROV to have more control and smoothly move. Balancing the vehicle during handling the load was one of the challenges that solved by putting the enclosure above the arm. Our strategy for ensuring balance is to locate two separated enclosure in the front and the back of the vehicle. The company considers this design to be a successful example of simple ingenuity.

Saudi ROV System Troubleshooting

Saudi ROV team performed many performance testing and system troubleshooting, especially when the outcome of a design was unplanned. Every problem was approached with a careful analysis of all the possible reasons the problem might have occurred, followed by a methodical testing to narrow down the source of the problem.

For example, when the ROV's electronics enclosures leak from the data thin wiring cables. The team then invented a quick and professional water pressure test apparatus through connecting 6.5 meter 1/2" pipe to each lid of the enclosure. Figure 7 shows the experiment.

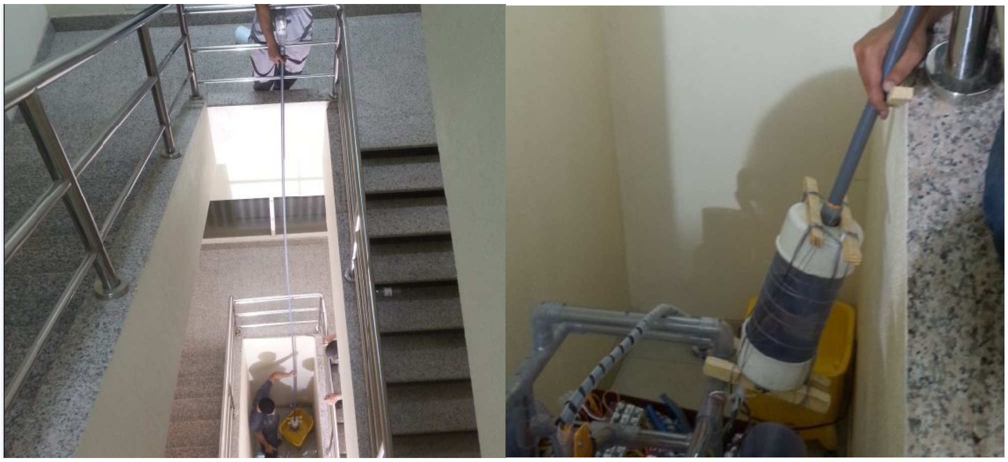


Fig. 7: Leakage test under 6.5 meter head of water column

Another example is manipulator jaw materials testing: Stress analysis for manipulator Jaw under 50 Kg load, Factor of Safety (FOS=4 and 1.82), see figures 8, 9 and 10.

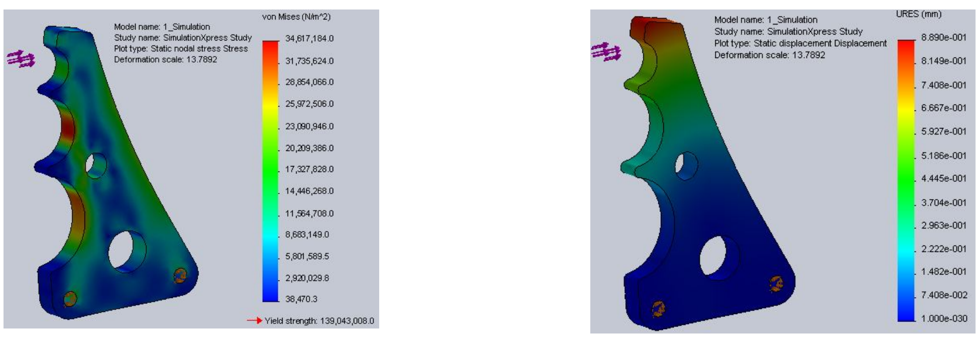


Fig. 8: Stress analysis for manipulator Jaw under 50Kg load applied to the web side normal to the fixtures (FOS=4)

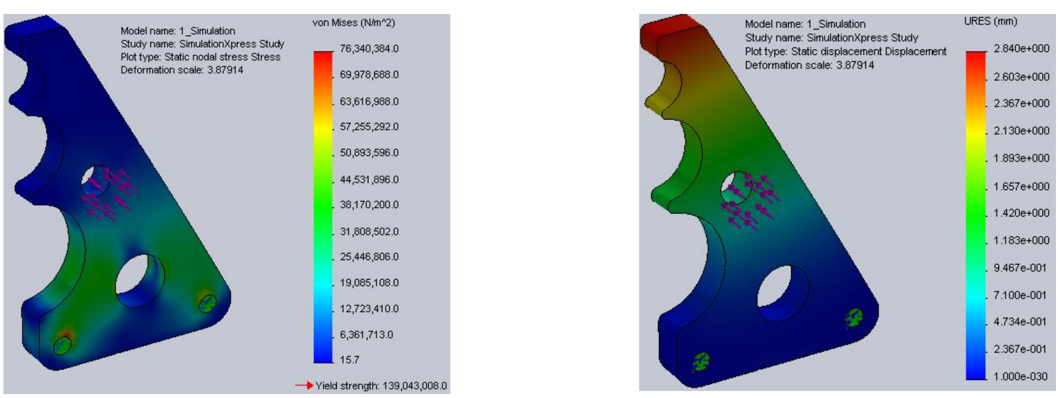


Fig. 9: Stress analysis for manipulator Jaw under 50 Kg load, Parallel to the fixtures (FOS=1.82)

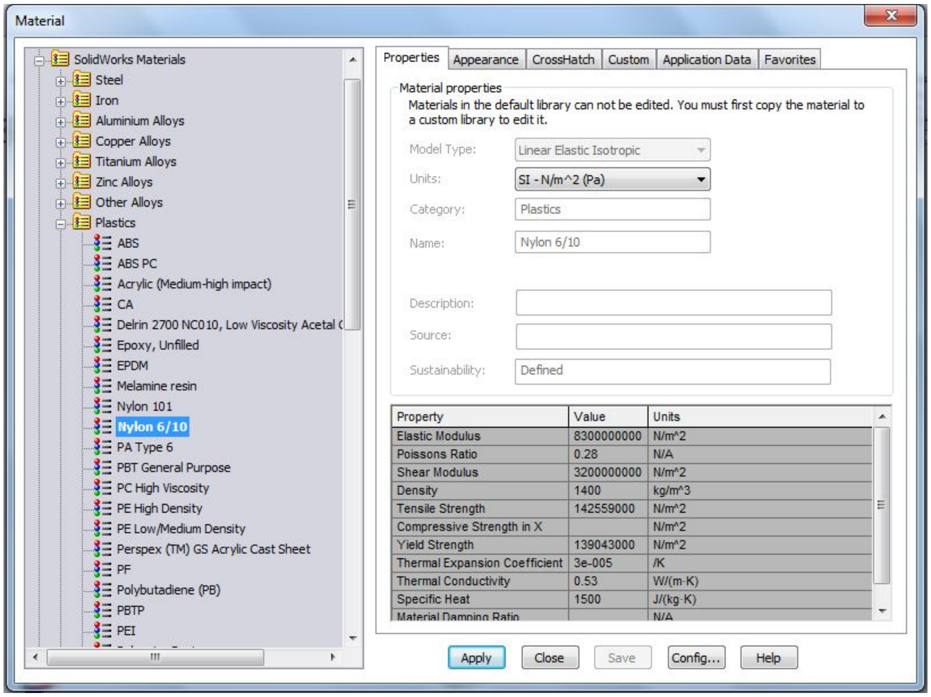


Fig. 10: The properties of material used for the manipulator (Nylon 6/10), Source *[SoliWorks library]*

ElEctronic Housing and Schematic

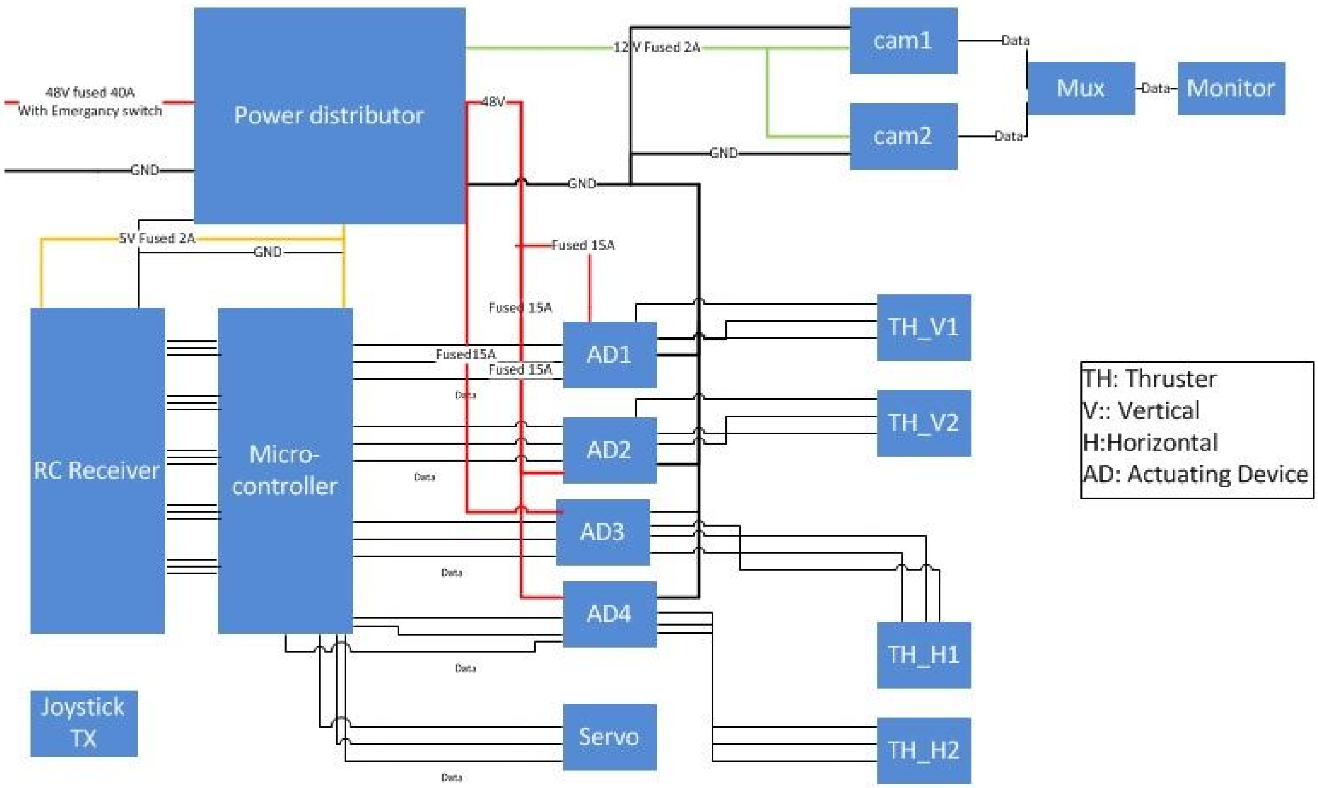
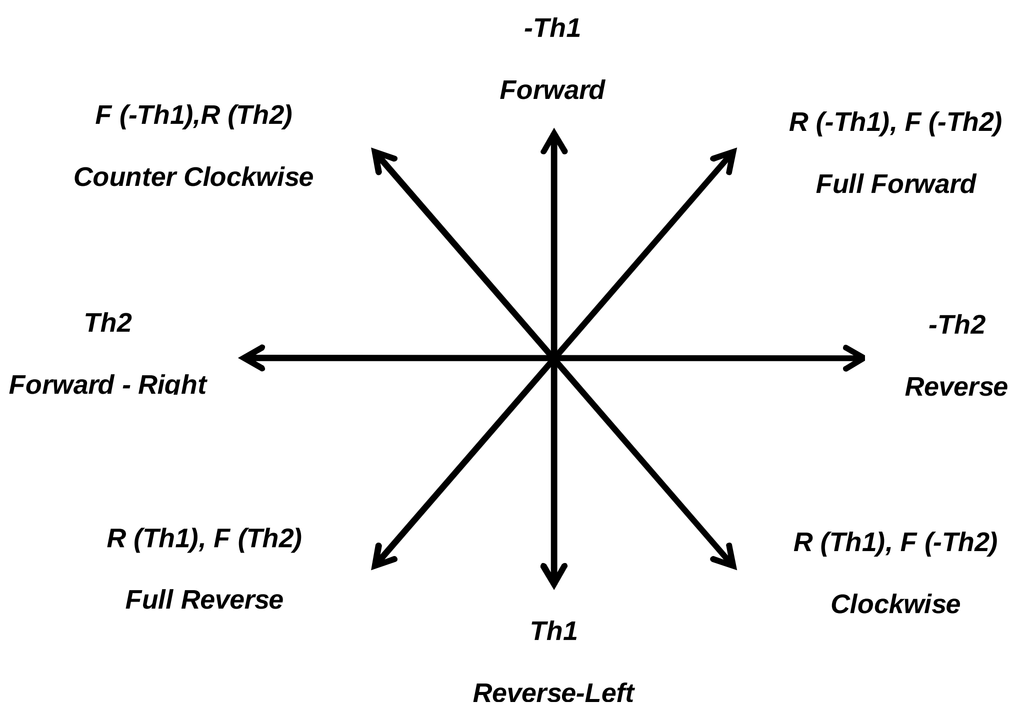


Fig. 11: Saudi ROV main control board

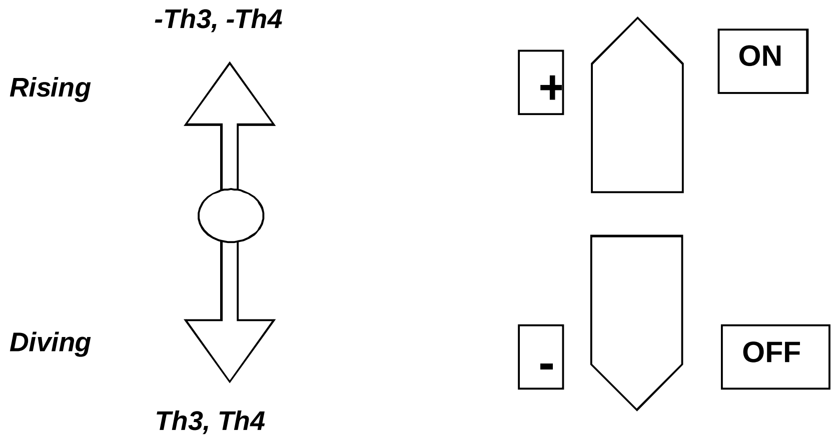
The ROV's control systems are housed in a 4" enclosure designed to keep electronics safe from soaking or moisture. It is essentially a 4" transparent pipe, sealed to be water proofed on both sides by a double O-ring attached to a PVC lid. The lid is sealed firmly to the pipe of the box using two ratchet lock spring clamps. All wirings were attached to the enclosure through silicon sealed junction.

Propulsion Control

The propulsion system for Saudi ROV is controlled with the Propeller Servo Controller (PSC) allowing the pilot to control up to 8 servos (16 using two PSC) by sending serial commands from a microcontroller or PC via its USB connection to the Joystick. The main control board of Saudi ROV is summarized in Fig 10. The designed control allows wireless communication between the control device (the joystick) and the ROV plant. A full motion design is investigated and implemented throughout different scenario regarding the competition tasks. The following figure shows the joystick arms and switches configuration:



Joystick Main Arm



Joystick Secondary Arm Grabber

Servo Arm ON/OFF Switch

Fig.12: Main settings for actuating devices calibration

DC Chopper

DC to DC converters are important in portable electronic devices such as remotely operated vehicles. Saudi ROV electronics requires three DC voltages: 48V from the main power DC supply source, +12V (for camera supply) and 5V (for the parallax board and the joystick RC receiver).

The thrusters are supplied via the main source. However, the control boards are functioning with both +12V and +5V. In this respective, we have opted for a step down DC to Dc converter.

The efficiency of the used converter is ensured and tested. The main characteristics can be stated as follows:

Input Voltage: 48V DC.

Output Voltage 1: +5V DC.

Output Voltage 2: +12V DC.

VDC Reinforced insulation.

Maximum Input Current 7.0 A.

Ambient Operating Temperature range: 0C to +70C.

Maximum output power under ambient temperature 185W.

An Emergency Button is implemented to ensure the circuit breaks in case of defaults or abnormal behaviors. The main circuit is protected by use of suitable fuses.

DC Power supply and data connection tests

To confirm the establishment of all the DC supply connection for both power and data we propose two flowcharts.

The power distribution flowchart presented in figure 13 allows checking the establishment of 48V, 12V and 5V. This step is crucial and must be performed and checked carefully each time the power supply is ON. A second flowchart related to the data connection is given in figure 14. In this figure we show the main steps that must be done when establishing the connection between the joystick and the RC receiver.

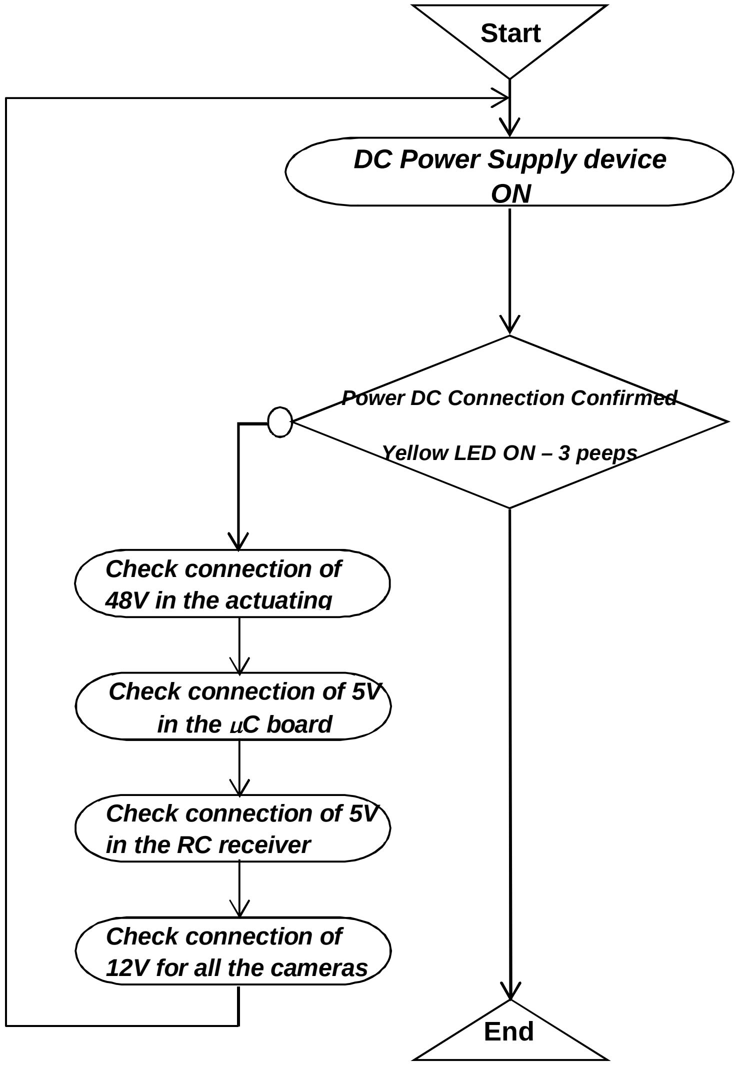


Fig. 13: DC power distribution flowchart

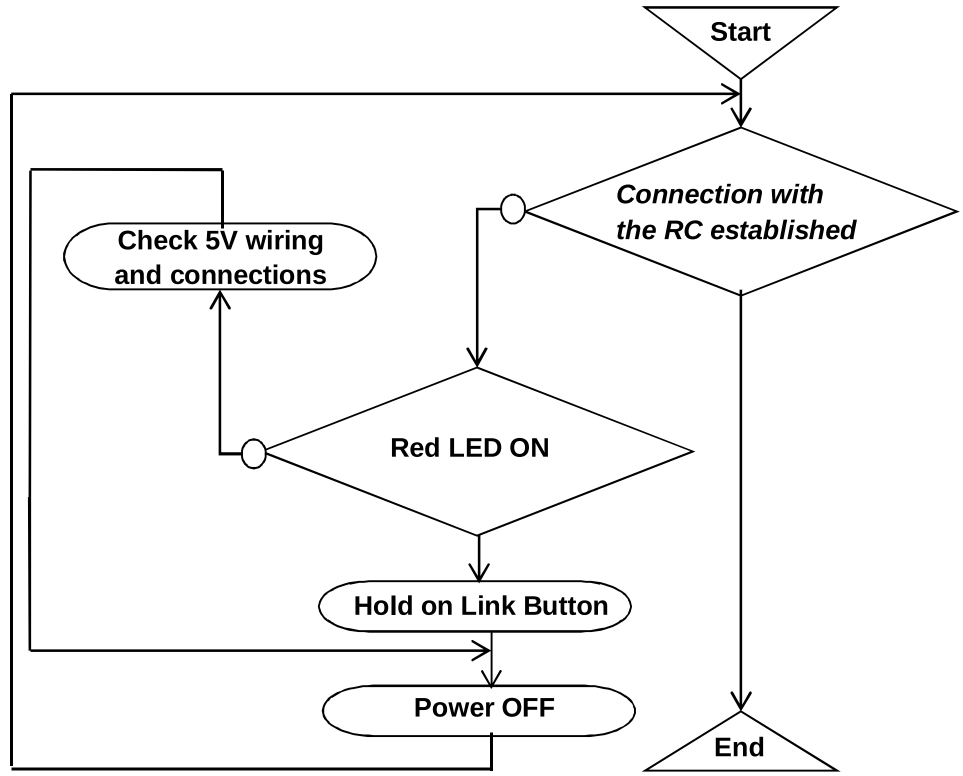


Fig 14: Data Connection flowchart

Transmissometer

Saudi ROV used an atmospherics photosynthetic futon Flux Density sensor to measure the water turbidity through the variability of light intensity. This sensor has been utilized extensively by limnologists, oceanographers and biologists conducting aquatic productivity studies and vertical profiling. The collected data from the sensor will be analyzed instantaneously through data acquisition system embedded in Lab View National Instrument software.

Recommendations foR Future Improvements

As we contemplate the design of Saudi ROV a few decisions stand out as those which could have been done more effectively. Although we are satisfied with the design, not every aspect reached its full potential. One Improvement we will make in the future is the design of the enclosure and wiring insulation. In addition, we are thinking of using pneumatic systems to enhance manipulator tasks and activities. The most strong and challenging enhancement would be increasing of the manipulator degree of freedom to move over three axis. This will be to enable it doing more tasks than clamping, like tilting.

Reflections

We are so proud to reach the stage of writing our reflections on Saudi ROV technical report. Before four months we were trying to identify the dilemma of MATE and ROV, prioritizing the level of each challenge to build Saudi ROV. Looking back at what has been accomplished throughout our design process many improvements have been made. Not only have we all learned a great deal of knowledge, but we have also built on our technical skills in the fabrication process for our ROV. We were also able to note future improvements that can be made to further developing our system as a whole.

RefeRences

- **Steven W. M.** and **Harry B**., *"Underwater Robotics: Science, Design and Fabrication"* , Marine Advanced Technology Education (MATE) Center, Technology & Engineering, Monterey, Calif, USA, 2010.
- **National Marine Educators' Association**, *"Current: The Journal of Marine Education"*, Vol. 19-20, National Marine Education Association, California, USA, 2003.
- **Harry B.** and **Vickie J.,** *"Build Your Own Underwater Robot: And Other Wet Projects"*, Westcoast Words, Edition 6, California, USA, 1997.
- **Suguru A.,** *"Advances in Robot Control: From Everyday Physics to Human-like Movements"*, Springer- Verlag, Heidleberg, Berlin – Germany, 2006.

Web Links

- http://www.marinetech.org/
- en.wikipedia.org/wiki/Category: Underwater_ robots
- www.ntnu.edu/amos/project-4 (Project **4**: Autonomous **underwater robotics** - AMOS - NTNU).
- http://more.unist.hr (Underwater robotics : present state and the future)

Appendices

Appendix A

Saudi ROV Mission Summary

Task #1: Complete a primary node and install a secondary node on the seafloor

This task involves the following steps:

• Transferring the SIA to the seafloor

• Installing the SIA so that it rests completely within the (BIA)

• Removing the CTA from the seafloor

• Inserting the CTA into the bulkhead connector on the BIA

• Pulling the pin to release the secondary node from the elevator

• Removing the secondary node from the elevator

• Measuring distance to find the designated location

• Installing the secondary node in the designated location on the seafloor

• Adjusting the legs to level the secondary node

• Opening the door of the BIA

• Removing the secondary node cable connector from the elevator

• Inserting the secondary node cable connector into the bulkhead connector on the SIA

Task #2: Design, construct, and install a transmissometer to measure turbidity over time

This task involves the following steps:

• Designing and constructing an optical beam transmissometer prior to the competition

• Installing the transmissometer in the vent field to monitor the opacity through the medium

• Detecting the relative changes in opacity

• Detecting the relative changes in opacity over five minutes

• Graphing the relative optical transmission (aka opacity) versus time on a video display

Task #3: Replace an Acoustic Doppler Current Profiler (ADCP) on a water column mooring platform

This task involves the following steps:

• Disconnecting power to the platform

• Turning the handle to unlock the hatch

• Opening the hatch

• Removing the ADCP from the mooring platform

• Installing the new ADCP into the mooring platform

• Closing the hatch

• Turning the handle to lock the hatch

• Reconnecting power to the platform

Task #4: Locate and remove biofouling from structures and instruments within the observatory

This task involves the following steps:

• Locate five areas of biofouling and removing all biofouling organisms

Appendix B

The propeller servo controller

The propeller servo controller is a powerful tool allowing the control of up to 16 servos by sending serial commands from a microcontroller or PC via serial or USB connection.

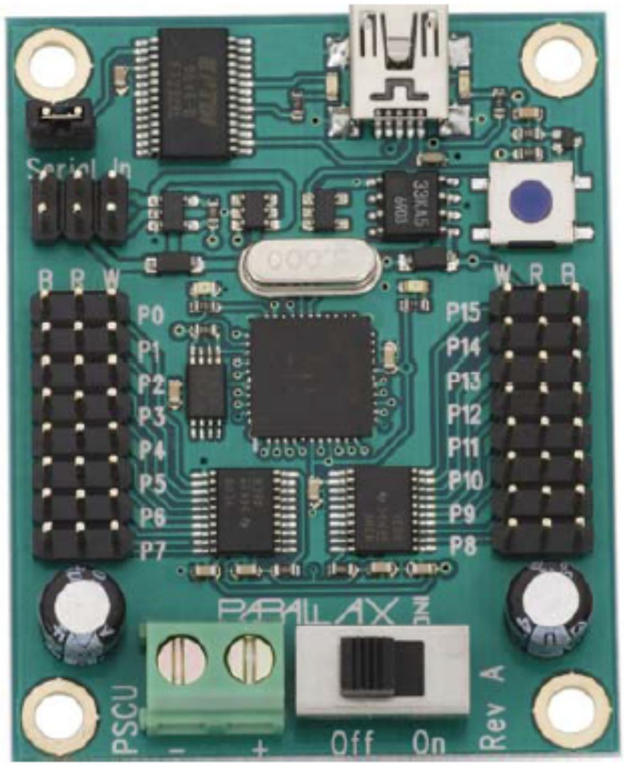


Fig. Z: The propeller servo controller

The Parallax Propeller chip, is a multi-core architecture parallel microcontroller. The program design can be developed via the Propeller Assembly language, and Spin interpreter (a multitasking high level computer programming language). The Spin Programming language and the "Propeller Tool" integrated development environment were exploited by Saudi ROV team to build a simulation environment. In this crucial step, the team tested the different operating modes of the thrusters and consequently defined the main calibrating settings of the actuating devices (ICE2 HV 60).

Several main reasons and advantages pushed the team to use propeller servo controller over other microprocessors:

- Its Multi-Core architecture
- Several programming languages: assembly language, spin code, 12 blocs graphical programming language.
- Open-source firmware
- Network Ready – two units may be linked to control 32 servos (via microcontroller only)
- Low cost

The main key specifications are the following:

- Power requirements: 5 VDC @ ~60 mA for logic
- Communication: Asynchronous Serial @ 2400 bps or 38.4 kbps (TTL or USB)
- Operating temperature: 32 to 158 °F (0 to 70 °C)
- Dimensions: 2.26 x 1.80 x 0.65 in (57.3 x 45.7 x 16.5 mm)

The Actuating Device

To ensure the maximum of reliability and efficiency, Saudi ROV team opted for the Phoenix ICE2 HV60 controllers. As an actuating device, the ICE2 HV60 offers a comprehensive feature set for thruster controlling; including:

- Direct entry governor mode,
- Auto-rotation with bailout,
- Soft start capabilities to protect the thrusters.

In addition, they can ensure a good immunity against noise and frequency disturbance, since they are isolated via an Optoelectronic circuit.

PHOENIX ICE2 HV

PHOENIX ICE2 HV 60 and 80 ESCs

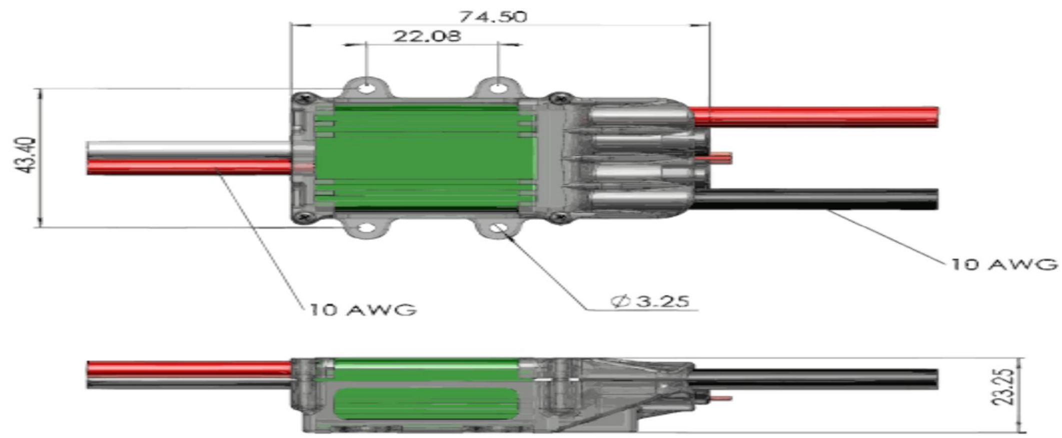


Fig. y: Phoenix ICE2 HV60 controllers

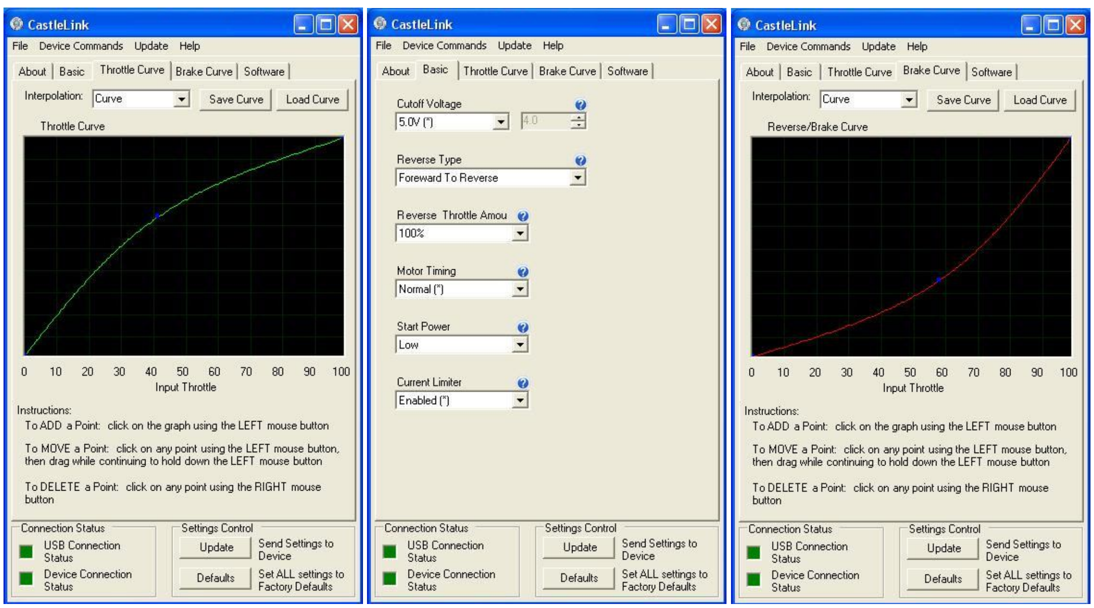
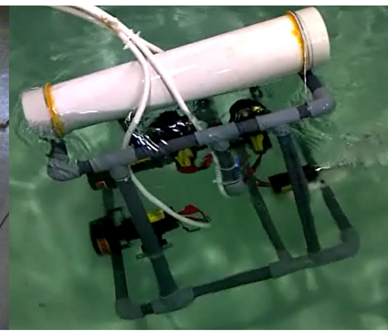
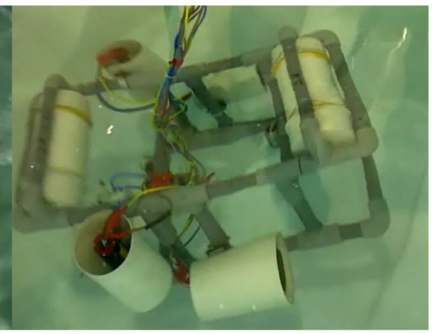
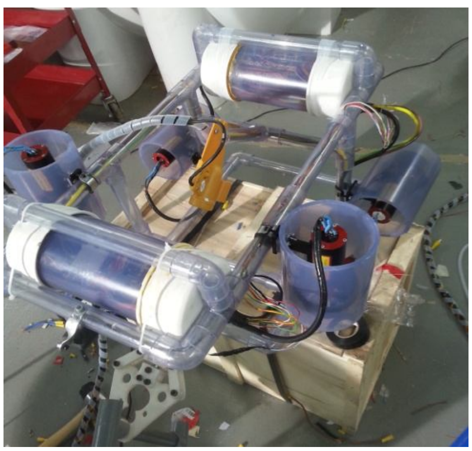
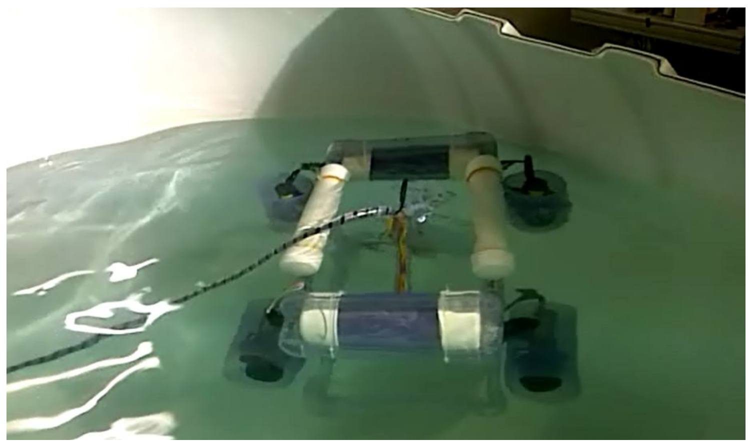


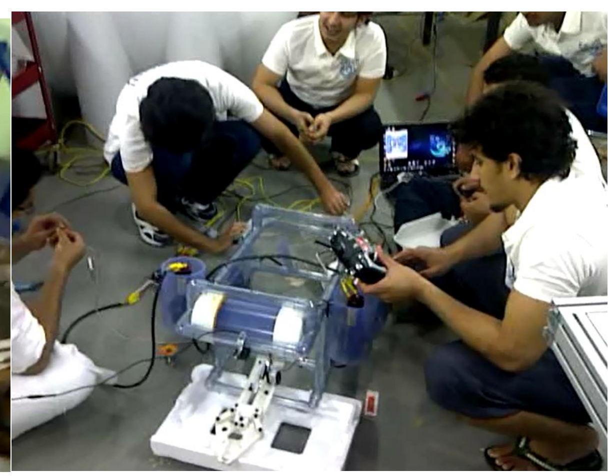
Fig. x: Castlelink calibrating software screenshot

To perform a smooth speed control of the ROV's thrusters, a calibrating step must be carefully done. In this respective the Phoenix ICE2 HV60 controllers are set up via the castlelink software in tow operating mode: Throttle Curve and brake curve. Optional settings are recommended to increase both safety and efficiency of the control process.

Appendix C

Selected Photo Gallery of Saudi ROV Team




Saudi
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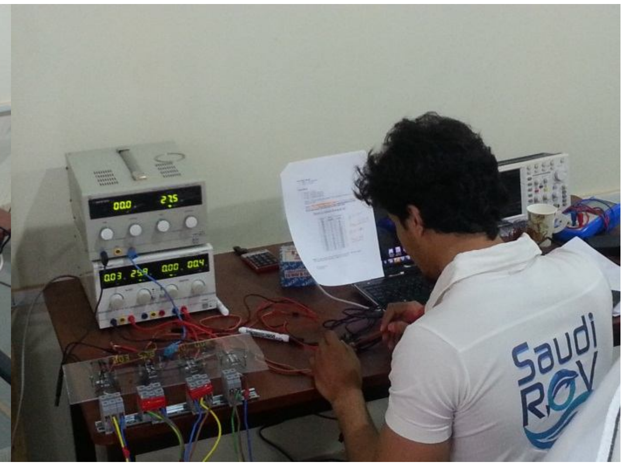
Saudi
ROV


Saudi
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