



## **DEVELOPMENT OF POWER MODULE OF SMALL-SCALE ROV FOR EDUCATIONAL PURPOSES**



**BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY  
(MAINTENANCE TECHNOLOGY) WITH HONOURS**

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**Faculty of Mechanical and Manufacturing Engineering  
Technology**

**DEVELOPMENT OF POWER MODULE OF SMALL-SCALE ROV  
FOR EDUCATIONAL PURPOSES**



**Mohd Shafiq Nazri Bin Kussim**

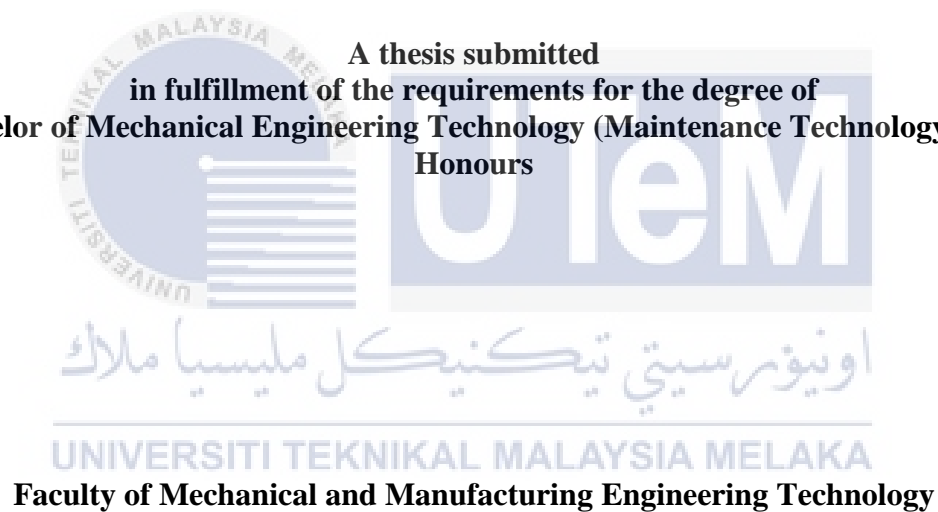
**Bachelor of Mechanical Engineering Technology (Maintenance Technology) with  
Honours**

**2022**

**DEVELOPMENT OF POWER MODULE OF SMALL-SCALE ROV FOR  
EDUCATIONAL PURPOSES**

**MOHD SHAFIQ NAZRI BIN KUSSIM**

**A thesis submitted  
in fulfillment of the requirements for the degree of  
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with  
Honours**



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2022**

## DECLARATION

I declare that this Choose an item. entitled “ Development Of Power Module Of Small-Scale  
Rov For Educational Purposes ” is the result of my own research except as cited in the  
references. The Choose an item. has not been accepted for any degree and is not concurrently  
submitted in candidature of any other degree.

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## APPROVAL

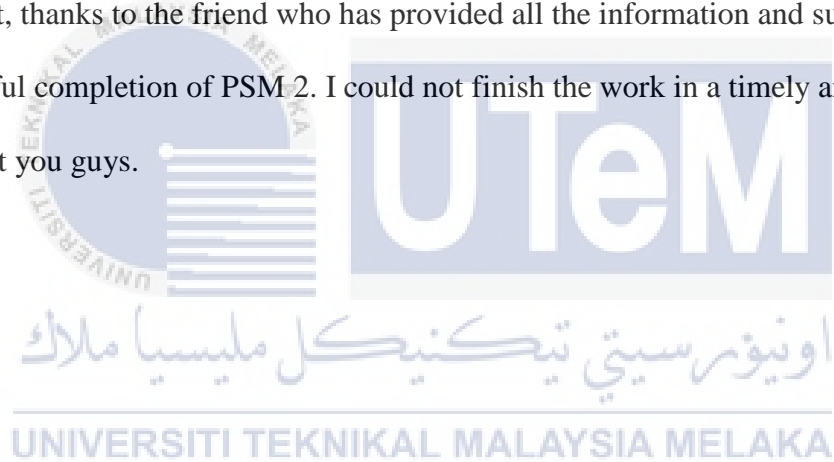
I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

Signature :   
Supervisor Name : Mohammed Noor Bin Hashim  
Date : 18/01/2022



## DEDICATION

My project is dedicated to my family and my friends. I used to understand that every task requires self-effort and advice from everyone. In addition, a particular sense of appreciation to my family who offer me every day a word of encouragement and prayers. I'm also dedicating my work to my supervisor who has helped me from start to finish. Last but not least, thanks to the friend who has provided all the information and suggestions for the successful completion of PSM 2. I could not finish the work in a timely and completed way without you guys.



## ABSTRACT

Day by day, technology are developing in all countries such as ROV technology in any sector including educational sector, but there are several obstacle in the process to build a ROV, which is the power module system. This paper describes the development of power module of small-scale ROV for education purpose with detail in every chapter. The objective of this paper is to develop a small-scale ROV power module and to fabricate a small-scale ROV suited for educational purpose, which is for high school students for learning. This small-scale ROV power module designed based on engineering design methods such as Morphological chart, conceptual design method and testing. The final dimension of the small-scale ROV power module was 175 mm x 118 mm x 62 mm in size with a thickness of 1-5 mm. Moreover, the small-scale ROV air and water tight container design were chosen because of engineering features, which is needed for buoyancy and safe for all electronic component, also allowing it to dive underwater. The power source enough to supplied to the whole ROV. The SLS machine was utilize to produce and fabricate the entire component of ROV including drilling and threading process. The study expected outcome is the development of a power module for a small-scale ROV for educational purposes, using a nylon plastic material. As a result, specific criteria was applied to select the most appropriate ROV power module for educational purpose including shape, material used, component used for system, fabrication or manufacturing method and dimension.

## **ABSTRAK**

*Hari demi hari, teknologi berkembang di semua negara seperti teknologi ROV dalam mana-mana sektor termasuk sektor pendidikan, namun terdapat beberapa halangan dalam proses membina ROV iaitu sistem modul kuasa. Kertas kerja ini menerangkan pembangunan modul kuasa ROV berskala kecil untuk tujuan pendidikan dengan terperinci dalam setiap bab. Objektif kertas kerja ini adalah untuk membangunkan modul kuasa ROV berskala kecil dan menghasilkan ROV berskala kecil yang sesuai untuk tujuan pendidikan, iaitu untuk pembelajaran pelajar sekolah menengah. Modul kuasa ROV berskala kecil ini direka bentuk berdasarkan kaedah reka bentuk kejuruteraan seperti carta Morfologi, kaedah reka bentuk konsep dan ujian. Dimensi akhir modul kuasa ROV berskala kecil ialah bersaiz 175 mm x 118 mm x 62 mm dengan ketebalan 1-5 mm. Selain itu, reka bentuk bekas kedap air dan udara ROV berskala kecil dipilih kerana ciri kejuruteraan, yang diperlukan untuk daya apungan dan selamat untuk semua komponen elektronik, juga membolehkannya menyelam di bawah air. Sumber kuasa yang cukup untuk dibekalkan kepada keseluruhan ROV. Mesin SLS digunakan untuk menghasilkan dan mengarang keseluruhan komponen ROV termasuk proses pengerudian dan benang. Hasil yang dijangkakan kajian ialah pembangunan modul kuasa untuk ROV berskala kecil untuk tujuan pendidikan, menggunakan bahan plastik nilon. Hasilnya, kriteria khusus telah digunakan untuk memilih modul kuasa ROV yang paling sesuai untuk tujuan pendidikan termasuk bentuk, bahan yang digunakan, komponen yang digunakan untuk sistem, kaedah fabrikasi atau pembuatan dan dimensi.*

اوينور سيتي تيكنيكل مليسيا ملاك

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In the Name of Allah, the Most Gracious, the Most Merciful

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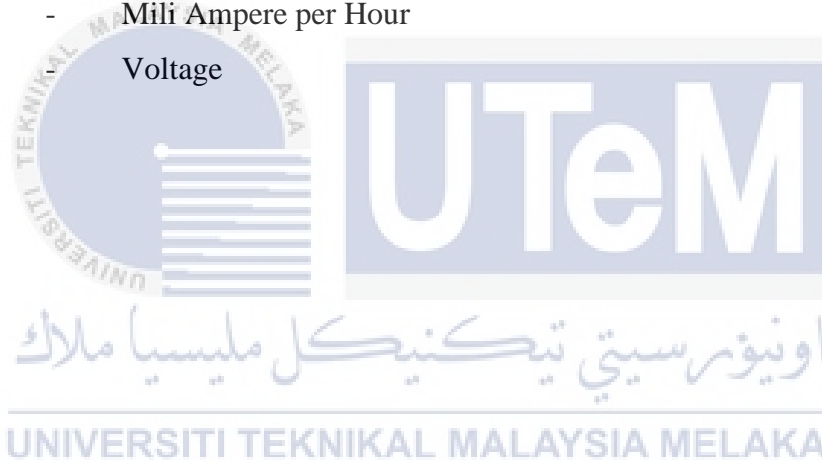
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## LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
ROV	-	Remotely Operated Vehicle
DC	-	Direct Current
LiPo	-	Lithium Polymer
RC	-	Radio control
3D	-	Three Dimension
SLS	-	Selective Laser Sintering
ESC	-	Electronic Speed Controller
mAh	-	Mili Ampere per Hour
V	-	Voltage



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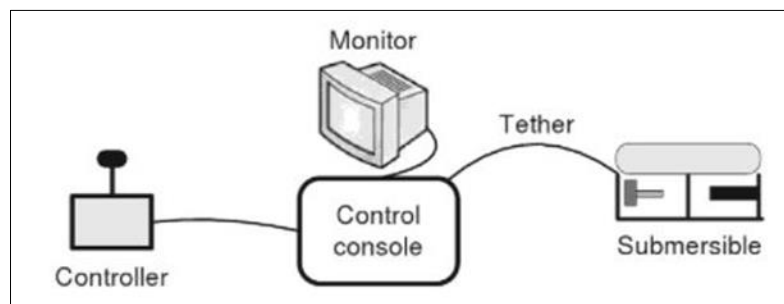


## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction

Unoccupied underwater robots or Remotely Operated Vehicle (ROV) are controlled by a human that is on a ship or boat, called remotely operated vehicles. They are easy to travel in water and are linked to the ship through the cable system which carries electrical signals between the operator and the ROV itself. A camera and lights are standard on most ROV. To maximize the ROV's capabilities, additional equipment is often added. Sonars, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration, and temperature are examples of external devices. ROV were first designed for industrial uses, such as pipeline checks and offshore platform structure checking. Today, however, ROV are used for a variety of purposes, many of which are analytical. They've proved to be incredibly useful in the field of ocean exploration. They're also used in aquaria for instructional programmes and to connect to live research expeditions through the Internet.



**Figure 1.1 Basic ROV system components** (*The ROV Manual, 2017*)

## 1.2 Background

Remotely operated vehicle (ROV) is a tethered robot, often employed for underwater operations. ROV operation is performed through a remote location control box, for example on onshore or on the floating vessel. This is the basic components of Remotely Operated Vehicle consist of; -

- i. System of Controlling and Navigation
- ii. Thrusters (Propulsion)
- iii. Light
- iv. Camera
- v. Body structure
- vi. Service module
- vii. Power module
- viii. Manipulator or cutting arm

Although the ROV industry has been developing internationally for some time, there are still just a few ROV manufacturers and suppliers in Malaysia. Instead of supporting the oil and gas industry, ROV capabilities can be applied to a wide range of uses, including search and rescue, education, ocean mining, fishing, and shipwreck investigation.

## 1.3 Problem Statement

The purpose of this project is to design a small scale ROV that suitable for high school students for their learning purpose. To be specific, the part was the power module of the small-scale ROV. The material selection should be considered to make sure the cost of making the ROV is low so that the school is able to afford it. The maneuverability of the ROV should be simple and easy for student to operate it underwater.

## 1.4 Main Objective

The purpose of this project is to design a small-scale of ROV that suitable for high school students for learning process. There are several objectives to achieve the purpose:

1. To design the concept of a small-scale power module of ROV that suitable for education purpose.
2. To fabricate the small-scale of ROV that suitable for education purpose
3. To investigate power needed for small-scale ROV

## 1.5 Project Scope

The scope of this project is to understudy all the matters involve with the designing, structuring and building the small-scale ROV. After the studies has complete, the fabricating process of the ROV prototype will be done, where the process involve are:

- Design a small-scale power module with dimension of 175 mm X 118 mm X 62 mm in size, with a thickness of 1-5 mm
- The plan ideas of this fabrication are small-scale, waterproof and light-weight below 3 kg for whole ROV
- The power required to power the whole ROV is supplied by a single pack of Lithium Polymer (LiPo) batteries.
- The ROV easy to control and suitable for education purpose

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter provides a study of the literature on the historical context, general structure, manufacturing process and components of the ROV itself. The historical context are briefly explained on this chapter. Also, on this chapter, the power system of the ROV are also mentioned. Lastly, the manufacturing process such as 3D printing are explained briefly in this chapter.

#### 2.2 History of ROV

The Royal Navy recovered trial torpedoes using a remotely operated submersible in the 1950s. The US Navy financed experiments into what was then known as a "Cable-Controlled Underwater Recovery Vehicle" in the 1960s (CURV). The Navy was able to conduct deep-sea rescue operations and retrieve objects from the ocean floor by CURV. When human divers were unable to manage most of the contemporary offshore construction in the 1980s, remotely operated vehicles (ROVs) became essential. Many old shipwrecks, including RMS Titanic, Bismarck, Yorktown and SS Central America, have already been found using underwater ROVs. However, a lot of work has to be done already! The depth at which most ROVs operate is more than half of the world's seas more than 3000 metres. There is always a lot to uncover in the water. ROVs are mostly used in the oil and gas industry, but they are also used in scientific testing, military uses, and underwater rescue operations for aircraft that have crashed and sunken ships. As technology improves, the ROV will perhaps one day in the near future be capable of exploring the deepest depths of the ocean.

### 2.2.1 ROV in Malaysia

There are several historical founded in Malaysia but only one are very useful for the research. In July 2006, an international conference titled Underwater System Technology: Theory and Applications was held at Universiti Sains Malaysia (USM) with the aim of improving underwater system technology in Malaysia (USYS06). According to Universiti Sains Malaysia's Assoc. Prof. Dr. Mohd Rizal Arshad,

*“This conference has provided a platform to researchers, scientists, engineers, academicians, as well as industrial professionals from all over the world to present their research result and development activities on underwater system technology and applications. USYS06 was organized by the School of Electrical and Electronic Engineering, Universiti Sains Malaysia, and co-organized by the Ministry of Science, Technology and Innovation (MOSTI), Malaysia and the Science and Technology Research Institute for Defense (STRIDE), Malaysia. Society for Underwater Technology (SUT) and University of Southampton was the co-supporter of the conference.” (Hic Su Dracones)*

Malaysia's undersea development, particularly the usage and development of remotely operated vehicles (ROV), is still in its early phases when compared with other countries. But nowadays a lot of company are offering services on ROV. Especially on oil and gas industries such as Nadi Marines Sdn. Bhd, Borneo Subsea Services (Malaysia), TWI Malaysia and many more. Subsea Explore Services (M) Sdn Bhd has created out a place for itself as the main local producer of underwater remotely operated vehicles (ROVs) since 2014. Firm co-founder and managing director Hazali Mansor established the company,

which handles subsea projects for PetroliaM Nasional Bhd (Petronas). Hazali said that during the company's early days in 2005, with a RM100 000 investment, a plan was created to propel the company towards being a ROV manufacturer. A 2,000 sq ft light industrial facility in Glenmarie, Shah Alam, surrounded by workshops, was used to house the design work for the ROV project, which was code-named "SSV 1." The project was completed in December 2007. According to Hazali, financial institutions have found it difficult to build a case for such complex projects since ROVs are a relatively new idea, and they were unable to establish the project's profitability at the time of application. In addition, despite the fact that they successfully tested the "SSV 1" at West Wharf, Kuantan Port Consortium, Kemaman, Terengganu in 2009, they were unable to enter the domestic market due to the presence of long-established international players in Malaysia, such as Oceaneering International (USA), Subsea 7 (Norway), TMT (Australia), Caldive (USA), Racal (UK), Sonsub (Italy), and others, including Oceane. In spite of the difficulties, they were awarded a contract in 2009 for the Caspian Sea Rig Support project for an Iranian oil and gas company, during which SSV 1 was able to dive as far as 1,000 metres below the surface of the sea. Petronas had had enough, and in 2012 the company was given a long-term contract for pipeline survey and inspection operations using remotely operated vehicles (ROVs). ExxonMobil Exploration and Production Malaysia Inc has awarded them an underwater inspection and maintenance project, which they are currently working on (ExxonMobil Malaysia).





**Figure 2.1 SSV 1 Project Subsea**



**Figure 2.2 Subsea Explore Services (M) Sdn Bhd project (*SubseaROV*, 2019)**

The ROV's main purpose is to assist the oil and gas industry with pipeline and platform construction, drilling, inspection, and maintenance, survey and for technical reporting. Aside from that, ROVs are used for underwater discovery and search and rescue missions. The Subsea Explore Services (M) Sdn Bhd offers a wide range of ROV classes and roles, as seen in Figure 2.3.



**Figure 2.3 Remotely Operated Vehicle Classes and Functions**

As shown in this research, the requirement for ROVs may be broadened to cover a wider variety of applications and scopes than previously considered. Aside from the oil and gas sectors, a tiny and basic ROV system may be utilised for river, lake, and undersea exploration for educational reasons, as well as for scientific research. In the fishing business, fishermen may easily utilise a remotely operated vehicle (ROV) system to observe the concentration of fish in a certain region of the sea and identify the optimum fishing site, allowing them to increase their daily harvest by as much as 50%. A remotely operated vehicle (ROV) will offer underwater CCTV surveillance video for individuals working in the maritime and security industries. Remotely operated vehicles (ROVs) will also be beneficial in marine research and exploration, since they will be able to monitor and capture the underwater living environment, and they will also assist divers in the identification of shipwrecks.

### **2.2.2 ROV in 3D printing and Laser Cutting**

Building a ROV has many ways but for a nowadays technologies are wide of the numbers. Such as 3D printing for ROV. Known as the Fifish V6, it is the world's first omnidirectional handheld underwater commercial ROV with an integrated 4K UHD camera. Qysea Technology, a leading ROV manufacturer, released the Fifish V6 in April 2019 with 3D-printed protective covers for its smart vector thrusters, a first in the ROV industry. In addition to a maximum dive depth of 100 metres and a diving duration of 4.5 hours, the Fifish V6 has an operating temperature range of -10 to 60 degrees Celsius and provides reliable results. Because of a sophisticated underwater camera and virtual reality technology, it offers users with an accessible and extremely immersive underwater world for scooting, recording, and inspection purposes. The design and development of the thruster protective cover for version 6 of the Fifish series faced several challenges when manufactured using



conventional processes: high cost, long lead time, and design limitations. Each concept revision costs over \$50,000 in injection moulds, with a 30-day manufacturing cycle. By that, underwater ROV in industrial models include custom designs, which are often constrained by the conventional design-manufacturing process.

Qysea Technology has been working with WeNext, an industrial additive manufacturing service bureau, since 2018 and has been using Farsoon's new Flight technology in their construction and series production processes. A wide build volume of 400 x 400 x 450 mm allows for the production of 150 protective thruster covers in a single build. Throughput is greatly improved, and cost per component is reduced, due to the efficient fibre laser and efficient processing. During the year 2019, Qysea successfully manufactured over 30,000 thruster protective covers for end-use parts in their consumer ROV development on Flight HT403P systems. Qysea was able to reduce the production time from over 30 days to less than 7 days through Flight technologies during design iteration. When compared to the conventional manufacturing process, the cost of series production of customised thruster protection covers is decreased by 80% for end-use component production. 3D printing also provides an alternate supply chain for lowering inventory costs, which is particularly useful for Qysea's rapidly evolving product line.

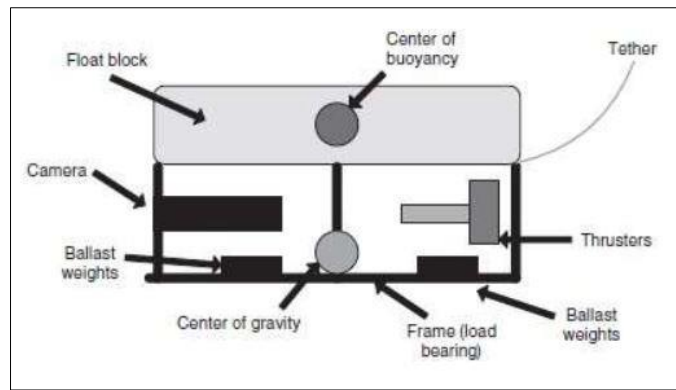
*"3D printing technology offers infinite possibilities for future underwater ROV innovation," says Ms. Li, Deputy general manager of Qysea. "Farsoon's Flight technology opened our eyes to a new level of advanced production speed, optimal yield and freedom of customisation. Now we have full confidence to achieve faster product development and additive series production at an economical cost."*(Engineer Live, 20)



**Figure 2.4 3D printed named The Fifish V6 ROV**

### **2.3 ROV Components**

A remotely operated vehicle (ROV) is basically a robot. The capacity of a robot to move independently of its immobile counterparts is what distinguishes it from the latter. It is possible to guide a robot with increasing degrees of autonomy in order to fulfil an aim or to achieve a set of goals when the robot is capable of mobility. Despite the fact that the ROV system is one of the most fundamental robotic designs, sophisticated tasks may be accomplished via the use of a variety of closed-loop navigation aids. (Subsea, 2019) By developing an effective and low-cost ROV that is appropriate for the user, it will be able to complete the work at task. This is owing to the fact that ROVs are often used to operate at sea depth levels, which may be hazardous to the divers out there. ROVs are intended to accomplish missions at specified depths and are used to do so. The rated depth and safety factors for all of the components utilised in the ROV must be adhered to in order for it to remain stable at the stated depth.



**Figure 2.5 Remotely Operated vehicle components (EDN, 2009)**

There are several major ROV components that are commonly used, as seen in Figure

3. The following are the main components of a ROV:

- i. Frame
- ii. Camera
- iii. Thrust
- iv. Light
- v. Tether
- vi. Ballast weights



Instead of cost reductions, the functionalities, efficiency and effectiveness of each built component are the major factors leading to outstanding small-scale ROV performance.

### **i. Frame**

The frame was created with the intention of serving as a platform for the components that will be added to the design. The frame must fit to accommodate the weight of the equipment while still being stronger. Its material can range from plastic to aluminium, depending on a variety of

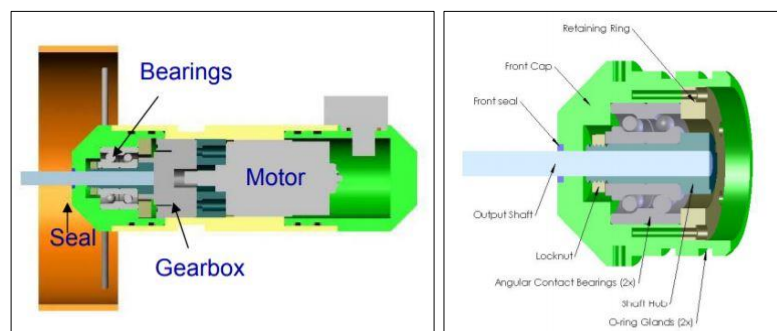
factors. Since weight is so closely linked to gravity and buoyancy, the material chosen is crucial.

## ii. Camera

The camera may be used to capture pictures or videos, as well as to record audio. As the vehicle runs deep below, the pilot only sees the onboard camera to provide a low-latency picture. In addition, the camera is essential for ROV safety as well.

## iii. Thrust

Thrusters are propellers that are operated by electricity or hydraulics that are used to steer the machine. Multiple thrusters are almost often present to provide movement in multiple directions. The thruster size chosen must be able to handle the weight of the ROV in order for it to lift the water with high torque. The propeller needs torque to rotate so it moves a massive amount of water at a slow speed on each rotation. Since the ROV is near neutral buoyancy or slightly positive buoyancy, a small amount of power is needed to keep it going at a steady depth. The constructional part of the thruster is shown in Figure 4 below.



**Figure 2.6 ROV constructional part (Franz Hover et al, 2005)**



**Figure 2.7 Thruster for ROV**

**iv. Light**

As the ROV dives further into the sea, it becomes necessary to use lights. It will aid the camera in obtaining sharper underwater pictures as a result of the addition. Lights that are suitable for use in water must also be capable of generating the proper colour of light. Orange light, for example, is preferable to white light because white light is more readily absorbed by the water than orange light, making it more appropriate.

**v. Tether**

Almost all ROV have a tether that transmits electrical power and/or signals to the surface, allowing the pilot to steer the vehicle and view the camera. Since radio waves do not reach very well across water, modern wireless technologies cannot be used to run a ROV. Wireless operation could be possible in the future to advancements in acoustic and optical modem technology.

#### **vi. Ballast weights**

Ballast weight is required to keep the buoyancy of the ROV under control.

The quantity of weight and air in the ROV must be appropriately controlled in order for the ROV's centre of gravity to be located in the correct place. If this is not done, the ROV may become imbalanced, which may result in rotational movement. In this scenario, it will be difficult for the ROV to perform its functions successfully.

### **2.4 Power System**

Because of the very high-speed thrusters, it is necessary to maintain stability against strong water currents, which means the ROV requires a significant amount of electricity. The umbilical cable that connects the ROV to the surface ship delivers power, commands, and other data to and from the ROV. This refers to the often-lengthy umbilical cable that connects the ROV to the ship; it may be several metres in length and is prone to substantial power dips while in use. As ROVs dive further and deeper into the ocean, the industry has a significant problem in increasing power transfer while simultaneously decreasing the weight of the ROV.

A Tethering Management System (TMS) is usually installed between the boat on the surface and the ROV itself in order to minimise the strain on the cables and the ROV itself as part of this process. It's possible that the TMS is as close as a few tens or hundreds of metres away from the ROV, but that there are many metres of lengthy cables connecting it to the boat in the background. This significantly reduces the amount of strain in the ROV, and it is a common industrial equipment found on the TMS station intermediate. It is also

the location where a step-down transformer lowers and rectifies the high alternating current (AC) voltage from the surface to a lower and more useable direct current (DC) voltage needed by the ROV. While ROVs are now utilised in electric applications, hydraulic pumps have traditionally been used in manipulators and thrusters. However, there is a growing trend in the industry to replace hydraulic pumps with electromechanical and electrical components.

For environmental reasons, it is necessary to identify and quantify any leaks in the robot's hydraulic systems, which is mandated by regulations. In the hydrocarbon exploitation and exploration industries, the costs of running and insuring these robots have risen dramatically as a consequence of these leaks, raising the cost of doing business. With this, especially in conjunction with the poor performance of hydraulic systems, the necessity for a transition in ROV technology to one that is more efficient and ecologically friendly is being pushed forward further. (*Elmom.Cn*, 2017)



**Figure 2.8 Electric Umbilical Cord and Hydraulic Power ROV power system**

There are many types of power supply for these ROV which contain on the surface and on the ROV itself. On the surface the choices of power supply is batteries or switching power supply and for the ROV either it use Lithium Polymer battery (Lipo)/NiMh or gel



cell. On the surface power, it can say that the supply is very safe, easy and common option that, when properly engineered, typically produces the best results.

The disadvantage is that the weight of the control wire does not usually support the ROV in terms of neutral buoyancy, which may result in the tether being less flexible under certain circumstances. This option, on the other hand, offers the most constant power since there is no limit to the amount of power that can be supplied from the ground, allowing the ROV to operate for an indefinite period of time. Because there are no limitations on space or weight, more powerful engines, lights, and other accessories may be utilised while maintaining the same overall size as the ROV. It is also necessary to have internal power or a power source in the ROV. This is still a very secure option, but it is, in my opinion, much more hazardous. It is possible to generate internal power in two ways: either by using tiny gel cells, which are sealed lead-acid 12v batteries, or by using Lithium-Polymer battery packs.

The usage of gel cells has a lower danger, but there is a limit to how much strength may be utilised at one time when using gel cells. For example, a 6Ah battery will not be able to sustain 12 amps of current demand for a long period of time since it is not designed to handle such a high amount of power. Lithium Polymer battery packs, on the other hand, have the ability to withstand current up to many times their capacity; but, when exposed to water, they react violently and produce hydrogen gas, which may create an explosion if a spark or other source of fire is present. (*ROV Project, P. System, 2014*)





**Figure 2.9 LiPo battery pack and Gel cell**

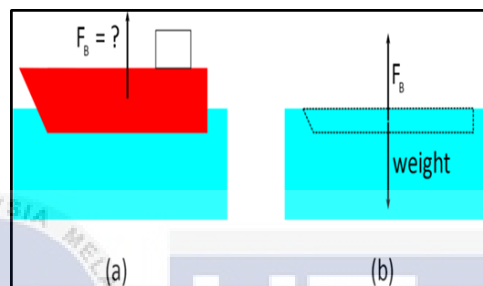
## **2.5 Buoyancy Force**

When an object or a person is submerged or immersed in a fluid, buoyancy is the upward force exerted by the fluid (*Nergaard et al., 2017*). At the time, it was common for objects to seem lighter and weigh less while submerged in water than when floating in air. Using a waterproof spring scale, a heavy object may be considered immersed in water to demonstrate this situation. Buoyancy is a result of the upward force a liquid or gas generates on a submerged object due to the pressure difference between the top and bottom of the object. Amount of buoyant force created by the weight of fluid displaced by the body is equal to this value. The buoyancy of many vehicles, including boats and ships, is essential to their proper operation.

While it has always been possible to determine buoyant force, it is usually difficult to do so. As explained by Boundless physics, a simpler approach uses the Archimedes Principle, which states that the buoyant forces acting on an object submerged in water are equal to the weight of the water that the object has displace. You may determine how buoyant an item is by taking into account its submerged half, and then determining the fluid's weight.

According to the Archimedes principle, the buoyant force exerted by a fluid on a submerged object may be determined. Objects that have a buoyant force greater than their

weight rise to the surface and float. The thing sinks if the buoyant force is less than the weight of the object. At its present depth, the item may stay buoyant if its buoyant force is equal to its own weight. Even though an item is submerged under water, the buoyant force is always there. The density is a crucial factor in Archimedes' principle. Figure shows that the buoyant force on the vessel (a) is equal to the weight of water that the vessel has displaced (shown in the figure by the dashed region) (b).



**Figure 2.10 Archimedes principle**

Density determines whether an item may float or sink due to its overall density. Only if its average density is lower than the surrounding fluid can it remain floating. This is because the density of the fluid has increased, resulting in an increase in mass and weight in the same volume. Since the displaced fluid has a greater weight, its buoyant force is greater than the object's.

The same principle applies to objects that are denser than the fluid they are submerged in. An object's submersion is determined by the fluid's density and the object's density's relation to the fluid's density. Additionally, the sub's stability and buoyancy must be balanced. Because of this, buoyancy calculations were utilised to evaluate natural behaviours and adjust future iterations of the system. The entire buoyancy of this submarine should be a little more buoyant than it is now. If the sub fails, it may return to the surface in

this case. The density and volume of an item are multiplied to get at its buoyancy. Ensure certain that the mass of the item in relation to the displaced volume is greater than the mass of water in the displaced volume.

$$F_b = \rho g V$$

Where:

$F_b$  is the buoyant force

$\rho$  is the density of the fluid

$g$  is the gravitational acceleration

$V$  is the volume of the fluid displaced

**Figure 2.11 Buoyancy force formula**

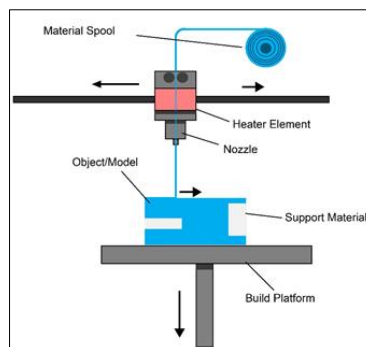
It is standard procedure to keep the vehicle's weight within a certain range while designing a ROV. To ensure that the vehicle descends to the surface in the event of a loss of power, buoyancy is necessary. Buoyancy control, often known as ballast, comes in two for such: fixed and variable. The vehicle's top is fitted with a large flotation pack made of syntactic foam as permanent ballast in order to achieve positive buoyancy.

A manufactured hollow sphere made of glass, ceramic, or polymer is the basic component of syntactic foam. Polymers are often used as binders. ROVs with variable ballast, on the other hand, might be heavier when diving in strong currents. An adjustable ballast tank is situated on the vehicle's sides or bottom and pushes water in and out of the vehicle (Ravalji, 2019). When the ROV's buoyancy centres are raised and its centre of gravity is reduced to the lowest possible level, maximum stability is obtained. The nose of most small ROVs may be moved up and down in the water by adjusting the placement of a ballast that is mounted to the vehicle. To generate buoyancy in the ROV, buoyancy blocks or modules consisting of materials with a lower density than water are required. The buoyant

material must also be able to bear the pushing force while operating at the greatest possible hydrostatic pressure.

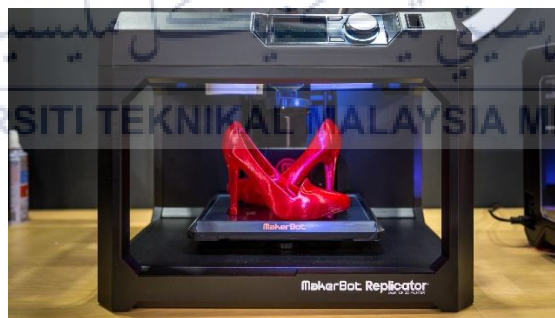
## 2.6 Manufacturing Process

Manufacturing is a crucial stage in the manufacturing process. It includes the conversion of raw materials to finished commodities via the use of equipment and methods. A manufacturing process is often performed as a unit operation, which means it is a single step in the chain of operations required to transform raw materials into completed products. Process manufacturing is a subcategory of manufacturing in which raw materials are transformed into products with a variety of physical properties and applications through a series of operations. The fundamental problem is a change in the produced item's material form or size. Modern manufacturing in the semiconductor business encompasses the advanced methods necessary to create and integrate product components. Frequently, quality assurance tests are conducted during or after the production process. The manufacturing process serves three purposes: it modifies the physical properties of the raw material, it modifies the shape and size of work components, and it modifies the dimension and surface polish of the work components.



**Figure 2.12 Schematic modern 3D printing (AMRG, Add. Manu. Research)**

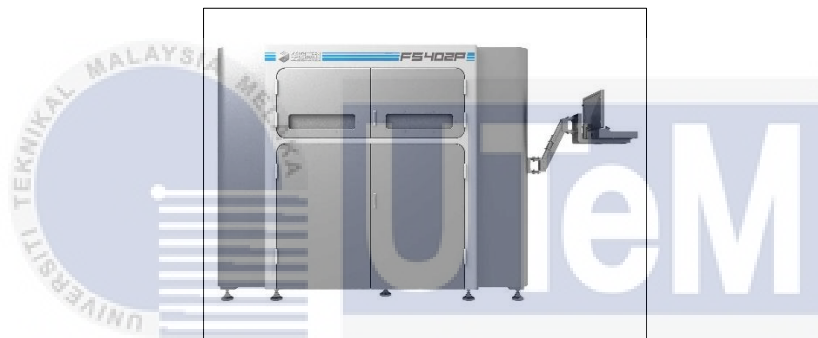
According to industry experts, 3D printing is a non-traditional manufacturing technology that is gaining traction in the modern day. Additive manufacturing is a process that involves building up successive layers of material until the final product is complete. Each 3D printer type has its own set of printing techniques, technology, and materials; each kind is defined by a unique mix of attributes. A 3D printer, computer-aided design (CAD) software, or a simple digital camera and photogrammetry programme, in addition to a 3D scanner, may all be used to make 3D printing models. The hand modelling technique used to generate geographic data for 3D graphics is akin to the plastic arts, which comprise the process of moulding plastic objects. Essentially, 3D scanning is the process of collecting digital data about an item's morphological properties and constructing a digital model of the thing from that data. While the printer's resolution is adequate for many applications, in other circumstances, creating a slightly larger version of the item in ordinary quality and then removing material using a higher-resolution technique might result in more accuracy.



**Figure 2.13 Modern 3D printer**

Selective laser sintering is a 3D printing technique that uses a laser to sinter powder layers by directing the laser at certain locations inside an area defined by a 3D model and combining the material to make a solid result. A similar technique is used in selective laser melting (SLM), except that the material is entirely melted before being sintered, allowing for a greater range of properties. SLS is a relatively recent technique that has been mostly

used to production processes and component reduction. A significant open-source software development community has formed, as have commercial variants of this kind of 3D printer. This procedure creates the model by extruding small material particles that solidify to form layers. Uncoiling a thermoplastic filament or wire into a coil in order to provide material to an ejection nozzle. The nozzle tip both warms and regulates the flow of the substance. Stepper motors are often used to drive the ejection nozzle in the z-direction and to adjust the flow as necessary. The mechanism is controlled by a microprocessor-based computer-aided manufacturing (CAM) software program, and the head may be adjusted in both vertical axis.



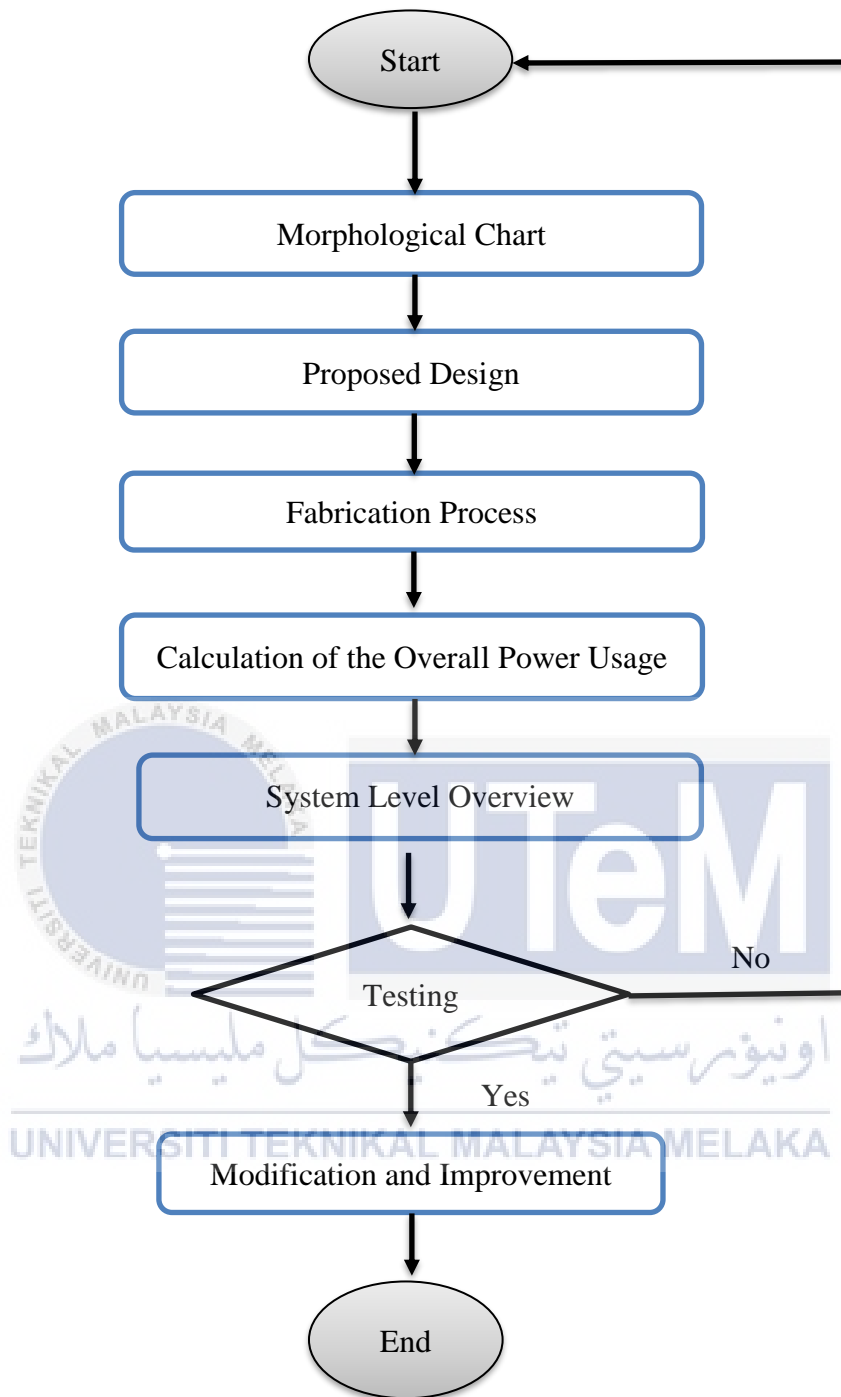
**Figure 2.14 China Farsoon SLS Machine**

## CHAPTER 3

### METHODOLOGY

#### 3.1 Introduction

To ensure that the project is successfully completed, it is to be sure that all the objectives can be accomplished. Process of accomplishing the project are subjected to a flow chart as shown in figure 3.1. The process to complete this project are based on the research of the study. This chapter section will discuss about the method of designing and produce the product. There are a lot of method based on mechanical requirements and concept of engineering. This chapter section will go through the process of designing the concept design and the final design of small-scale ROV. Significant strategies are used depending on various standard and engineering concept especially in mechanical engineering terms. The total power used by all of the equipment in the design may be used to determine the size of the power supply that will be required. This chapter also describe the designing development process, fabricating, and venture for the entire project. In the end, the completed small-scale ROV will be tested and any improvement or adjustments must be carried out.



**Figure 3.1 Process of Flow chart for Power Module of small-scale ROV**



### **3.2 Morphological chart of overall design for power module of small-scale ROV**

A morphological chart describes a product from one of several product categories. Morphological charts, also known as concept combination tables or function-means tables, are a type of design approach that is used to generate a list of integrated conceptual design concepts for a design challenge. A table is created by deconstructing the design issue and putting all of the important functions in a column. The main procedure of the morphological technique is to divide the overall design challenge into multiple criteria based on Table 3.1, in order to create solution principles for each criterion. Systematically integrate criterion solutions into various detailed solutions, and then assess all of the combinations. Merging options is a phrase used to describe the process of combining options. It then chooses the best idea. Consolidate common arrangements into various full arrangements on purpose and decide on all combinations of concept or design. A idea was the combination of possibilities. At that time, the best concept for the product was chosen; the morphological chart may be seen in chapter 4.

### **3.3 Design Concept**

A design problem is described in terms of observation, and experience. The idea originates from the morphological chart, where the concepts related to the object's character were formed. The weight and sealing is the most important factor in selecting the best idea to be approved. The benefits of this decision-making approach are that subjective opinions may be rationalised in favour of one option over another. The ideas are scored using the advantages and disadvantages will be discussed briefly on results of the projects.

#### **3.3.1 Proposed Design of Power Module of small-scale ROV**

The suggested design concept for the service module of the mini ROV is to design and sketch using Inventor software to get an overview of the product design in order to

achieve customer satisfaction based on the final weight in conceptual design's method, and then to test the design.

### 3.3.2 Exploded design

Every component of the design, including the end cap, front cap, and electronic tray, battery tray, and light tray has been built according to the number that represents it on each one of its individual parts. This two complete part of power module is needed because it is a part of ROV which buoyancy is needed for the ROV. Each component has its own set of measurements, as well as its own set of applications for which it is used. It shown in figure.



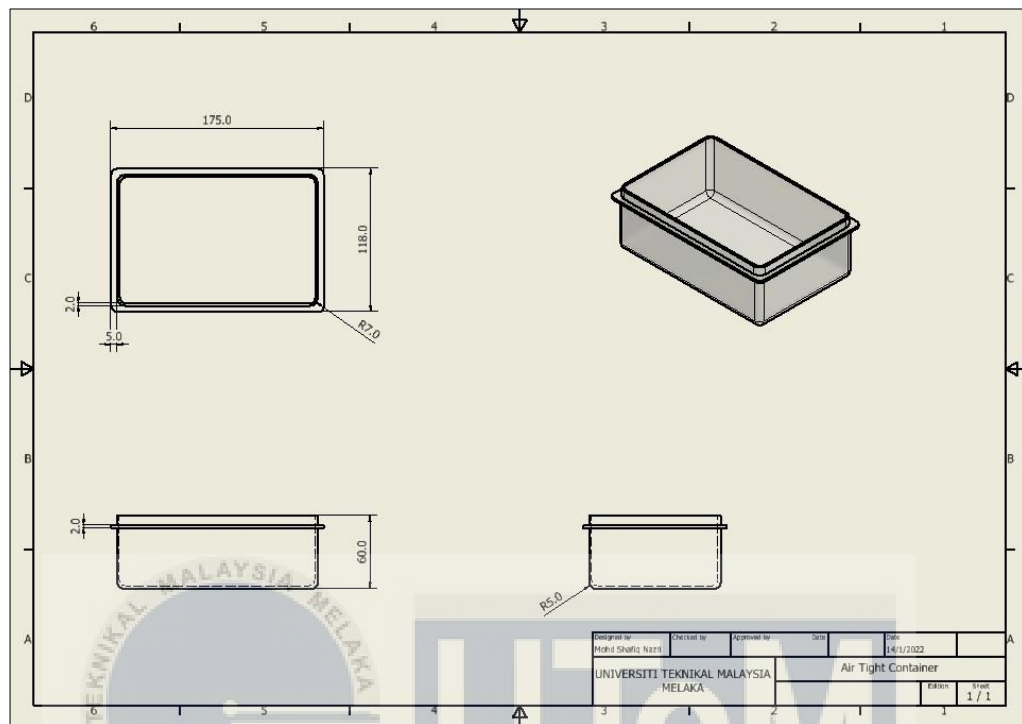
**Figure 3.2 Exploded view part of Power Module**

### 3.4 Part Design

#### 1. Housing

The housing is the part of the components that as housing all the components that are inserted into from the Power Module area. This section is important because it combines all of the components and serves as the focal point for the primary source of force or energy. The isometric perspective is scaled 1:2. While their measurement is based on the part's size including height, width and length. The matrix of all

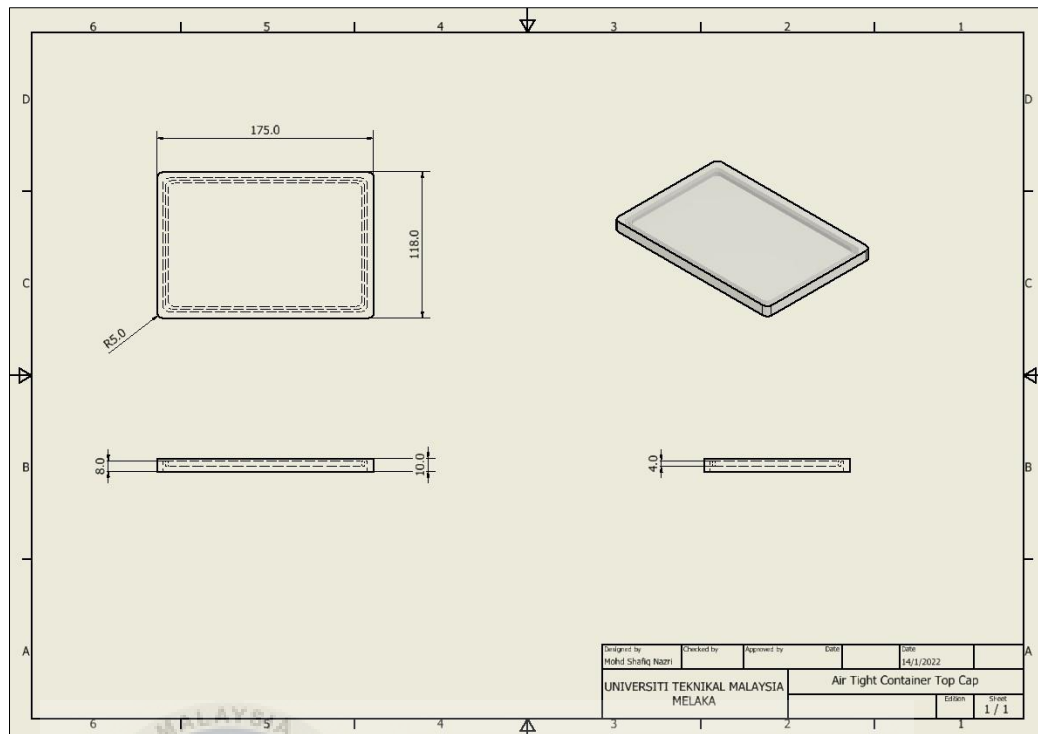
measured components has been set to millimeter. The housing part shown in the figure 3.3.



**Figure 3.3 Housing Part Dimension**

## 2. Top Cap

This component is important for front view, since it is a part of container and keep it waterproof and also keep the air inside as a buoyancy. This part is important since it also serves as a seal for all electrical components, preventing them from becoming wet and malfunctioning. It uses a 1:2 scale for all isometric views, including the top, front, and side views. While their measurement is based on the part's size including height, width and length. The matrix of all measured components has been set to millimeter. The top cap part shown in figure 3.4.



**Figure 3.4 Top Cap Dimension**

### 3.5 Fabrication of selected design

Nylon was selected for the fabrication of the ROV's power module because to its durability, yield strength, light weight, and cheap cost, among other characteristics. The ROV's power module is 175 mm x 118 mm x 62 mm and has a thickness of about 1-5 mm. To begin, the ROV's power module (housing) was developed in three dimensions using Autodesk Inventor 2020. Top cap for housing air tight container was designed independently using dimensions that met the small-scale ROV's requirements. At that point, all of the plan models for the ROV's housing were assembled and combined into a single model. The measurements and drawings for each component of the housing design will be used to manufacturers the frame's Nylon utilising SLS machines. The SLS machine handled all of the shaping and cutting, while the apprentice handled installation. Finally, each component was rebuilt and reorganised to form the power module for the ROV. The illustration depicts

the real design of the ROV's power module, which was created using Autodesk Inventor 2020.

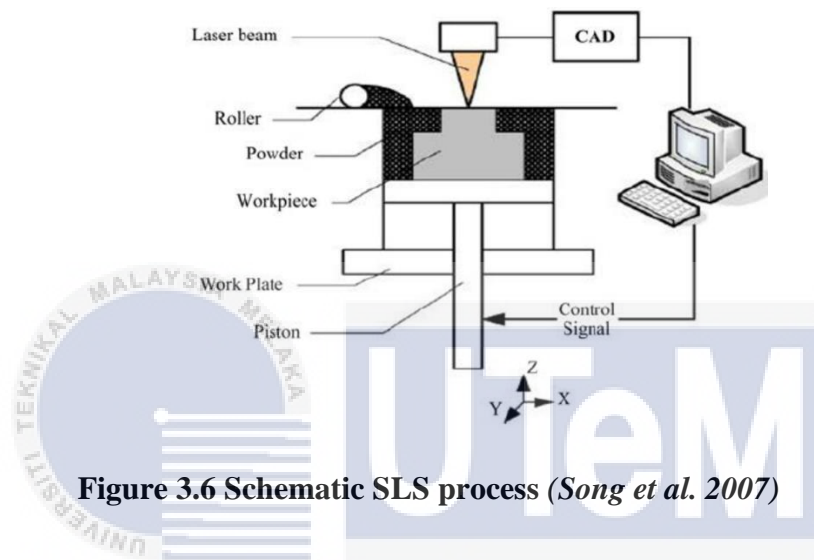


**Figure 3.5 Assembled Part of Power Module**

### **3.5.1 Selective Laser Sintering (SLS) Machine**

The operation of testing the machine's settings was performed to ensure that the whole system functioned effectively. By putting the Nylon powder volume in the powder tray, the SLS machine determines the entire production time necessary, including cooling time. The cooling phase was critical in order to minimize flaws in the component throughout the subsequent manufacturing processes. When a component does not get enough cooling time, it is prone to bending flaws, which is particularly true when the component has a thin wall thickness. Additionally, another issue was detected, such as a component that fractured due to a lack of cooling time. Production time is estimated to take up to 20 hours, depending on the amount of parts to print.

Following the 3D printing procedure, the manufactured component needed to be purified using a powder purify station and a bead/sand blaster machine to remove any nylon powder. Pneumatic energy was used to clean the component in a bead/sand blaster machine. After the examination was complete, all components needed to be inspected for symptoms of failure. Finally, each component of the ROV's frame was rebuilt and reassembled.



**Figure 3.6 Schematic SLS process (Song et al. 2007)**

### 3.6 Calculation of the Overall Power Usage

When the items to be used are determined, the total power consumption is calculated by dividing the rated power consumption of each item by the number of items. For example, the power used by the thruster system may be calculated by multiplying the current demand by the voltage supply. The same procedure applies to the rest devices.

### 3.7 System Level Overview

When all of the system completely installed, the complete diagram and process of system need to be explained on how this small-scale ROV worked and ready to any error and problem possibilities.

### **3.8 Build and Testing**

Certainly, after all of the other equipment have been installed and configured, the project can be started by constructing and testing the project both outside and within the water. The illumination and propulsion systems of the small-scale ROV, as well as the control and navigation systems, will be tested.

### **3.9 Modification and Improvement**

Finally, but certainly not least, changes, adjustments, and enhancements will be made in order to guarantee that the project's goals are achieved. Because the model is considered education purpose and it is on a small-scale, many enhancements may be made in order to further extend the ROV capabilities.



## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 Introduction

Six sub-systems were used in the construction of the small-scale ROV power system. System requirements, testing options, and techniques of testing are all covered in this part of the text. Our project requirements and material/system limitations had to be taken into consideration before we could choose which product to use. Each system has at least two options. Weighing the advantages and disadvantages of each method, we arrived at the best selection for the school and students.

#### 4.2 Floatation

Floatation was one of the subsystems of the small-scale ROV. The ROV needs floatation in order to keep buoyant and avoid sinking to the bottom. The floating mechanism was directly attached to the ROV frame, often on the top, to avoid the rollover that may occur with bottom mounted floats.

##### 4.2.1 System Requirement

There are several methods for providing float for a ROV, but the best way for each is frequently decided by the size and weight of the ROV, as well as the targeted depth. The requirement on depth is induced by the loss of buoyancy experienced by many materials when exposed to water pressure. A 3D printed ROV, for example, is small and light, with a



shallow-water depth rating that enables pool noodles to function as buoyancy. We wanted a ballast tank solution for our ROV that was sturdy, simple to deal with, and reasonably priced.

#### 4.2.2 Option and selection

**Table 4.1 Floatation options**

	<b>Polyurethane</b>	<b>PVC tubes</b>	<b>Water/air tight container</b>
<b>Pros</b>	<ul style="list-style-type: none"> <li>• Cheap</li> <li>• Easy to machine and deal with</li> <li>• Rigid structure</li> </ul>	<ul style="list-style-type: none"> <li>• Cheap</li> <li>• Hard structure</li> </ul>	<ul style="list-style-type: none"> <li>• Less expensive than other</li> <li>• Easy to use</li> <li>• Lightweight</li> </ul>
<b>Cons</b>	<ul style="list-style-type: none"> <li>• Compress at high pressure</li> <li>• Heavy</li> </ul>	<ul style="list-style-type: none"> <li>• Have to buy a long PVC</li> <li>• Heavier than polyurethane</li> </ul>	<ul style="list-style-type: none"> <li>• Detailing primer/sealant is difficult to find and work with.</li> <li>• If crack, it needs to buy others container</li> </ul>

We utilised these calculations to determine that around 282840.7246 cubic millimetres of syntactic foam created adequate buoyancy. This wasn't a horrible size; but, since syntactic foam is constructed with minute glass beads, it is incompressible, therefore cutting this material may be problematic. Furthermore, sealing the material is difficult, and the sealant itself is difficult to locate. The scuba bladder would have been the most effective approach to enhance buoyancy since it would have enabled us to modify the buoyancy at any moment.

However, we would have required a mechanism to regulate it, which would have added even more upkeep and complexities to an already complex system. Welded cylinders,

similar to those seen on pontoon boats, are another viable alternative, but they must be welded to the frame and are quite heavy. The fourth alternative was polyurethane foam, which we ultimately chose. While not cheap, this foam was quicker to manufacture

### **4.3 Waterproof Housing**

On the small-scale ROV, there were two watertight housings; one held all of the underwater ROV's electronics, while the other contained the batteries. This section discusses the housing needs and possibilities, including the material used and the contents. It is concluded by the testing that was conducted on the selected airtight container.

#### **4.3.1 System requirement**

When it comes to developing a waterproof housing for robots, it seems that each manufacturer has their own set of standards. The requirements were simple: it had to be waterproof to a depth of one (1) metre, lightweight, and inexpensive.

#### **4.3.2 Options and selection**

However, these three conditions result in three very divergent choices. Below is a general introduction of waterproof housings; this includes a review of homemade 27 choices (Air tight container), water-resistant boxes (3D printed boxes), and marine-grade waterproof bottles.

**Table 4.2 Housing options**

	<b>Bottles</b>	<b>3D printed boxes</b>	<b>Air tight container</b>
<b>Pros</b>	<ul style="list-style-type: none"> <li>• Cheap</li> <li>• Easy to find supplies</li> </ul>	<ul style="list-style-type: none"> <li>• Inexpensive</li> <li>• Can design in many ways</li> </ul>	<ul style="list-style-type: none"> <li>• Cheap</li> <li>• Waterproof to any depth depends on build</li> <li>• Easy to find supplies</li> </ul>
<b>Cons</b>	<ul style="list-style-type: none"> <li>• Thin</li> </ul>	<ul style="list-style-type: none"> <li>• Occur porosity</li> <li>• Heavy build</li> <li>• Hard to find SLS machine</li> </ul>	<ul style="list-style-type: none"> <li>• Quality of sealing</li> </ul>

We chose an airtight container due to the depth restrictions we faced. This was disappointing since the other options would have been much simpler to work with, but we were limited in our options. There are still a few possibilities for airtight containers: immerse in water, permanently seal, or air filled with detachable top caps. The next section discusses the advantages and disadvantages of each.

**Table 4.3 Testing process**

	<b>Immerge in water</b>	<b>Permanently seal</b>	<b>Air filled</b>
<b>Pros</b>	<ul style="list-style-type: none"> <li>• The most efficient kind of waterproofing</li> </ul>	<ul style="list-style-type: none"> <li>• Second the most efficient kind of waterproofing</li> </ul>	<ul style="list-style-type: none"> <li>• Maintenance s</li> </ul>
<b>Cons</b>	<ul style="list-style-type: none"> <li>• Cost added</li> <li>• Maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Less efficient</li> </ul>

We picked an airtight container with removable top caps since our ROV was experimental and the electronics needed to be swapped out and serviced on a frequent basis. This was not a more expensive or risky option, but it was required for the kind of ROV we constructed.

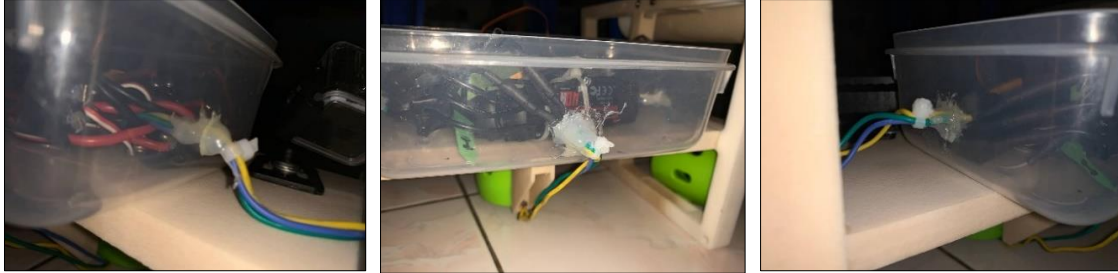


**Figure 4.1 Waterproof housing**

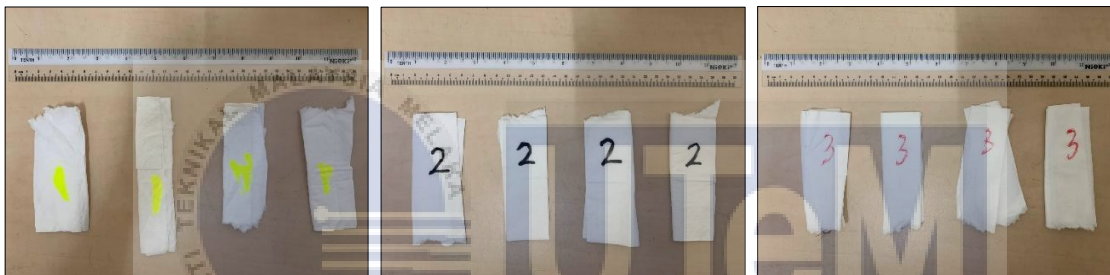
### **4.3.3 Testing**

Waterproof housing evaluation was simple. The top caps were installed and secured, and the housings being immersed for a day to test for visible leaks. They got away without getting soaked. This enabled us to ensure that they were watertight before putting all of the equipment aboard. At larger depths, there was a higher probability of it spilling. However, since we did not have the time to examine the airtight seal container in a 2 metre deep water pool, we had to wait until the whole ROV was conducting its final inspection before testing it in water. We don't see any leaks in the electronics container while submerged in water. We decided to examine the ROV at 1 metre depths since none of the seals leaked. We had thought it would be OK, but we didn't have the time to replace it or manufacture a 3D box. We were mistaken, but students will be able to change housing in the future. More detail for air tight container on Appendices B. Mass, volume, area, and most crucial is stress strain analysis and safety factor.

The type of sealing we use two different type of sealing which is epoxy resin and coating with hot glue to make sure the housing completely safe to dive underwater.

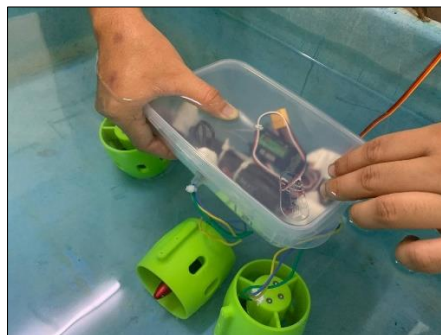


**Figure 4.2 Sealing the air tight container**



**Figure 4.3 Image of sample sealing test after sealing on air tight container**

For the test resulting that, the three sample has been put inside the air tight container and wrap the tissue on the wire that gone out from housing to thrusters and servo motor, the air tight container was completely waterproof and able to dive underwater. We run a test by soak in water for 30 minutes for each sample from 1 to 3, which all of samples are completely dry. All internal components are safe ready to install to small-scale ROV.



**Figure 4.4 Sealing testing in water**

#### **4.4 Power Source**

For large commercial ROVs, the conventional power source is an above-water conversion that converts energy to a high operating voltage that is transmitted down the tether. Since the voltage across the wire drops considerably over a long distance, they do this. Our system was designed with safety in mind. As a result, we were unable to use a traditional high-power system. As an alternative, we chose battery power. Apart than that, we operate the small-scale ROV using simply an RC controller and receiver.

##### **4.4.1 System requirement**

Because of the range of potential technologies, battery and power supply constantly seem to limit the potential of remotely operated vehicles. We wanted to examine a few variables and choose the best power source for our project. These criteria included the ability to be used safely, low voltage, having a minimum of 300 Watt per hours since the thrusters is high speed brushless thruster, being lightweight, compact enough to fit within an airtight container, being affordable, and straightforward to charge.

##### **4.4.2 Options and selection**

Because of these limits, we investigated three basic approaches of powering our vehicle. The first was a high voltage power system, which employed inverters well above water's surface to supply high voltage electricity to the robot through a line. As a second alternative, we looked into lead acid batteries, and as a third option, we looked into lithium polymer batteries. The preceding is an evaluation of the advantages and disadvantages of each approach.

**Table 4.4 Power source options**

	<b>High Power Voltage Line</b>	<b>Lead Acid</b>	<b>Lithium Polymer (LiPo)</b>
<b>Pros</b>	<ul style="list-style-type: none"><li>• Endless power supply</li></ul>	<ul style="list-style-type: none"><li>• Easy to charge</li><li>• Cheap</li></ul>	<ul style="list-style-type: none"><li>• Smallest battery per KWh</li><li>• Lighter in weight</li></ul>
<b>Cons</b>	<ul style="list-style-type: none"><li>• Large inverters</li><li>• The most expensive</li><li>• Larger tether</li><li>• Hazards</li></ul>	<ul style="list-style-type: none"><li>• Larger than LiPo battery</li><li>• Heavy</li></ul>	<ul style="list-style-type: none"><li>• Hard to charge</li><li>• Expensive</li></ul>

We determined that Lithium Polymer (LiPo) battery were the best option among these three options. Although high voltage power lines would have taken up less space onboard the ROV and would have lasted longer than batteries, they would have extended setup time and required supplies, therefore we chose battery operation for safety considerations.

Additionally, due to the size and weight limits of our ROV, we determined that Lead Acid batteries were unsuitable. We had to overcome charging issues with LiPo batteries since these obstacles require that each cell be examined individually while charging, but the cost was well worth it. To recharge these batteries, they must be taken from their airtight container, and they need a particular charger that monitors the current battery six cells to guarantee appropriate charging.



**Figure 4.5 Lithium Polymer batteries**

#### 4.4.3 Testing

Thus far, we've powered the camera and thrusters using a 30C 2200 mAh 11.1V Lithium Polymer battery, which has performed as planned. The thrusters testing section table (4.5.3) and motor controller testing section discuss the thruster test in further depth (3.5.2.3). We tested the ROV in water and discovered that after a 30-minute deployment, it still had half of the charge remaining. The lights and camera were on during this deployment, and the thrusters were always in operation. By the way, the lights and camera were not powered directly by LiPo but rather by a separate battery.

We were limited in power by the ROV's size, thus the voltage, current, and power for each of the component are shown below.

**Table 4.5 Power for each component**

Component	Current (A)	Voltage (V)	Source	Power(W)	Idle (W)	Dive/Surface (W)	Driving (W)
Z thrusters (1)	20	12	Spec/test	240	0	240	120
X thrusters (2)	20	12	Spec/test	240	0	0	240
Electronic Speed Controller (ESC)	40	7.4-11.1 (depends on battery)	Spec/test	240	0	240	240
<b>Total (W)</b>					0	480	600
	<b>Watt hour required</b>	<b>Battery pack voltage</b>	<b>Amp hours required</b>				
<b>Worst case (driving) for 1 hour</b>	720	11.1	64.86486486				

Amp hours calculations,

$$\text{Watt hour required} \div \text{Battery Voltage} = \text{Amp hours}$$

$$\frac{\text{Power (Watt)}}{\text{Battery (V)}} = \text{Current (A)}$$

$$\frac{720W}{11.1V} = 64.86486486A$$



Since there are other components as independent power source, below are the current, voltage and power for each component.

**Table 4.6 Independent power component**

Component	Current (A)	Voltage (V)	Source	Power (W)	Idle (W)	Dive/Surface (W)	Driving (W)
<b>Camera</b>	0.3	3.7	Spec	1.11	1.11	11.1	11.1
<b>Light</b>	1.2	3.7	Spec	4.44	4.44	4.44	4.44
<b>RC Remote Controller</b>	4.6 (4 Pcs AA batteries)	6 (4 Pcs AA batteries)	Spec/test	27.6	27.6	27.6	27.6

## 4.5 Propulsion

Thrusters and motor controllers are included in the propulsion section. They pair up to control the ROV's speed and direction. It was important that they function in combination with the ESC and RC receiver contained inside the electronics container in order for us to propel the small-scale ROV through the water.

### 4.5.1 Thruster

The ROV was dragged through into the water with three thrusters. They were chosen among three distinct options based on their depth range, relatively low cost, as well as low power usage.

#### 4.5.2 System requirement

There are several thruster alternatives, and since this was to be a small enthusiast class robot, we were limited to a selection. The thrusters needed to be reduced, low-voltage (12-24v), powerful enough to propel the ROV, easy to install and operate, economically priced, and compact.

#### 4.5.3 Options and selection

During this study, we discovered three possible options: a handmade thruster configuration created from bilge pumps, a Seabotix brushed DC thruster, and a brushless DC underwater propeller. The advantages and disadvantages of these various thrusters are listed below.

**Table 4.7 Propulsion options**

	<b>Bilge pump</b>	<b>Seabotix brushed thruster</b>	<b>Brushless underwater propeller</b>
<b>Pros</b>	<ul style="list-style-type: none"><li>• Small</li><li>• Very low power consumption</li></ul>	<ul style="list-style-type: none"><li>• 150m depth rating</li><li>• Low power consumption</li><li>• Operate within 24V range</li></ul>	<ul style="list-style-type: none"><li>• 2000m depth rating</li><li>• High power thruster</li><li>• Operate minimum 12V up to 24V</li></ul>
<b>Cons</b>	<ul style="list-style-type: none"><li>• Low thrust</li><li>• Depth rating of less than 15m</li></ul>	<ul style="list-style-type: none"><li>• Not powerful as brushless underwater thruster</li></ul>	<ul style="list-style-type: none"><li>• Brushless maintenance and use</li><li>• Can't use battery directly</li><li>• Can't idle for a long time</li></ul>

Despite the fact that the ultimate size and weight of the ROV dictated which thrusters we could utilise, we nevertheless compared what was available.

We considered bilge pumps for our project at first, but rapidly sought for alternatives. Although bilge pumps are simple to use, they lack the depth rating and power required to move a robot of our size. The second option we evaluated was a brush motor produced by Seatibox, and although it has an average depth rating and is strong, we decided against working with it because of rotor limitations such as limited heat dissipation capacity. This resulted in our ultimate thruster selection, the underwater brushless thruster.

This was our conclusion since it was the finest overall thruster of this size. Despite the fact that we had to utilise a specialised motor controller, we still had to find out how to use and operate the thruster. And then there was the ESC. It has a depth rating of 2000m, works in the power range we chose, can be used with simple motor controllers, has a high-speed thruster, and consumes little power. As a result, it was an ideal choice for the small-scale ROV.



**Figure 4.6 Underwater thruster**

#### **4.5.4 Testing**

To enhance drag and make the ROV lighter, two thrusters were mounted to a Nylon 3D printed ROV frame without a grabber in front. We did our testing using a motor controller

(RC ESC), a battery, and an RC controller to operate the thrusters. One team member held on to the test equipment as it was submerged in the L106 X W73 tiny pool. The ROV was able to transport the ROV's 2.979kg weight with the help of its two thrusters. We were still able to move at half power, but we couldn't accurately describe our pace. Test results revealed a speed of around one foot per second at maximum power.

## 4.6 Motor Controller

### 4.6.1 System requirements

However, we narrowed our alternatives down to three based on the following criteria: small size, power handling capability, ease of use and affordability.

### 4.6.2 Options and selection

The three options that were considered were the Cytron MDDS10 motor driver, Cytron MDD10A and the Electronic Speed Controller (ESC) 40A. These were compared and a list of pros and cons are in the tables below for ease of reference.

**Table 4.8 Motor controller options**

	<b>Cytron MDDS10</b>	<b>Cytron MDD10A</b>	<b>Electronic Speed Controller (ESC)</b>
<b>Pros</b>	<ul style="list-style-type: none"> <li>• Dual channel</li> <li>• LED indicator</li> <li>• Brushed motor controller</li> <li>• Accept signal from Radio Control (RC)</li> <li>• Easy to use</li> </ul>	<ul style="list-style-type: none"> <li>• Dual channel</li> <li>• Brushed motor controller</li> </ul>	<ul style="list-style-type: none"> <li>• Brushless motor controller</li> <li>• Very easy to use</li> <li>• Compact size/small</li> </ul>
<b>Cons</b>	<ul style="list-style-type: none"> <li>• Expensive than others</li> </ul>	<ul style="list-style-type: none"> <li>• Less expensive</li> </ul>	<ul style="list-style-type: none"> <li>• Single channel</li> </ul>

	<ul style="list-style-type: none"> <li>• Size</li> </ul>	than MDDS10 <ul style="list-style-type: none"> <li>• Lack of monitoring abilities and programming capabilities</li> <li>• Size</li> </ul>	<ul style="list-style-type: none"> <li>• Cost per ESC</li> <li>• Different type of ESC which reversible or irreversible</li> </ul>
--	--	--	--

Research and consideration were given to these three motor controllers. Because of the Cytron MDD10A's size and lack of monitoring capabilities, we came to the conclusion that it should not be utilized. Moreover, we concluded that the Cytron MDDS10 should not be utilised since it costs more money, and unfortunately, we use brushless motors for our project.

That led us to our ultimate decision, which was to choose Electronic Speed Controllers (ESC), the simplest method possible. This ESC is less expensive than the MDD10A. In addition, each ESC can only manage one thruster motor. As a result, we'll need to spend out for three electronic speed controllers (ESCs) to power three thrusters. As there is a time limitation on ordering, we are forced to purchase an irreversible ESC from a nearby store.

#### 4.6.3 Testing

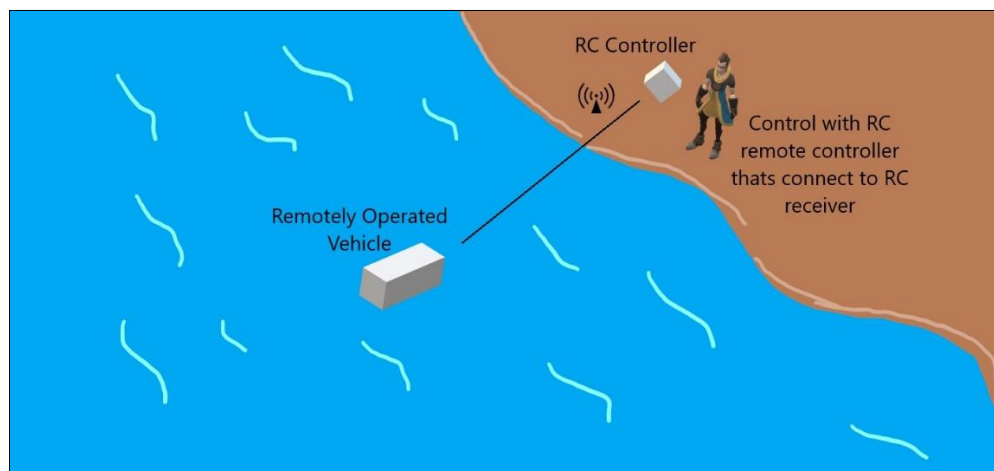
The ESC was tested by communicating with thrusters and supplying a defined current towards the thrusters to alter their speed using an RC remote transmitter coupled to an RC receiver. This was done at both full and half speed. Able to drive and dive on single analogue on remote controller.



**Figure 4.7 ESC calibration RC controller to RC receiver**

#### **4.7 System Level Overview**

The small-scale ROV communicates continuously with the operators through a wireless RC receiver that links the console to the robot. During scientific missions, the console might be one of three types: joystick RC controller, computer, or tablet. The user may operate the ROV and see the live feed from the camera installed on the small-scale ROV using this console. During a mission, data may be retrieved and stored to the storage. This information, as well as the small-scale ROV, may be utilised in the future for research missions by university students, as well as scientists and faculty members.

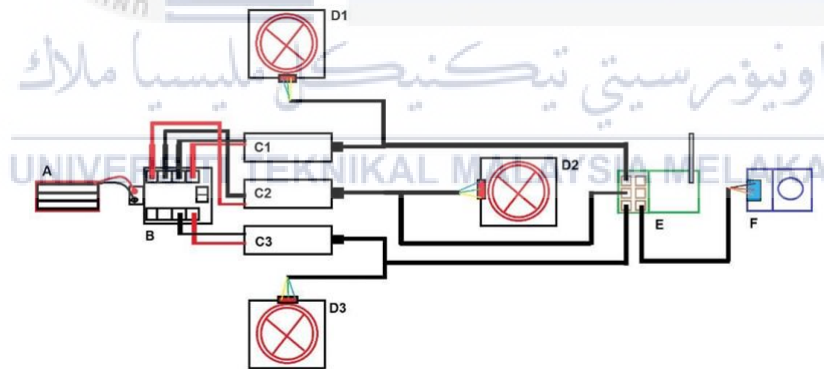


**Figure 4.8 Shows the ecosystem of the ROV**

Since, our ROV can't dive too deep in the water, but it still has functional thing that high-power ROV can do. Small-scale ROV can be deployed from a boat or from on land, allowing for ease of use.

#### 4.7.1 Component block diagram

Figure 4.9 shows the ROV's component block diagram. An airtight main electronics container contains the ESC motor drivers, battery, and radio control receiver. The lights and camera, on the other hand, are not controlled by the electrical component and operate independently. The thrusters are controlled by the ESC motor drivers. Servo motor to control grabber will connect directly to RC receiver. The battery pack is kept inside an airtight container and supplies power to the whole system. The RC receiver receives orders from the topside station, which is an RC remote controller, for controlling components and driving thrusters, as well as for collecting video data.



**Figure 4.9 Block diagram of small-scale ROV**

This configuration is a pilot console in which the camera stream is presented on an external device, data is shown on such a smartphone screen, and the user controls the ROV using a manual RC joystick controller.

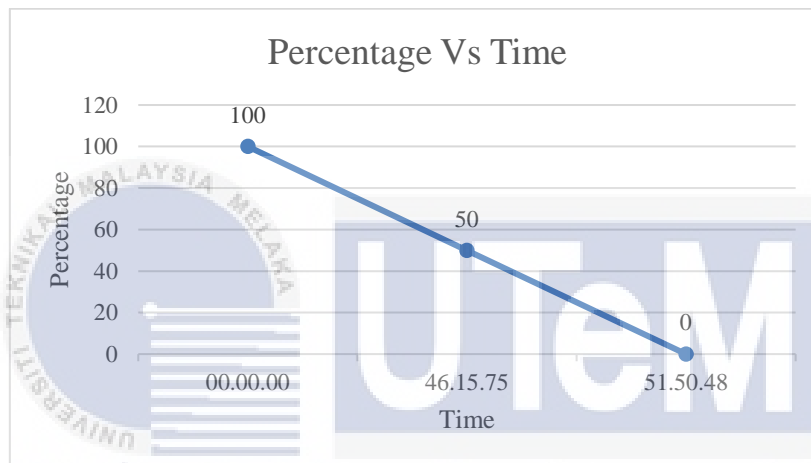




## Testing Monitoring Time and Response 1

**Table 4.9 Testing monitoring time and response 1**

Time	Impact	Response
00.00.00	High	Work greatly with full power of thrusters
46.15.75	Medium	Slow response from RC receiver and thruster work on low speed
53.50.48	Low	Thruster did not accept response from receiver and led indicator on RC receiver slowly fade. (receiver also depends on battery)

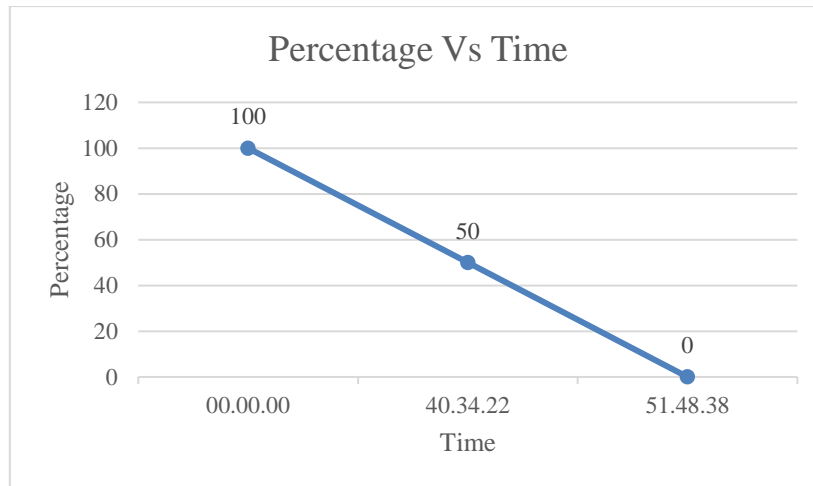


**Figure 4.11 Graph percentage vs time monitoring test 1**

## Testing monitoring and response 2

**Table 4.10 Testing monitoring and response 2**

Time	Impact	Response
00.00.00	High	Work greatly with full power of thrusters
40.34.22	Medium	Slow response from RC receiver and thruster work on low speed
51.48.38	Low	Thruster did not accept response from receiver and led indicator on RC receiver slowly fade. (receiver also depends on battery)

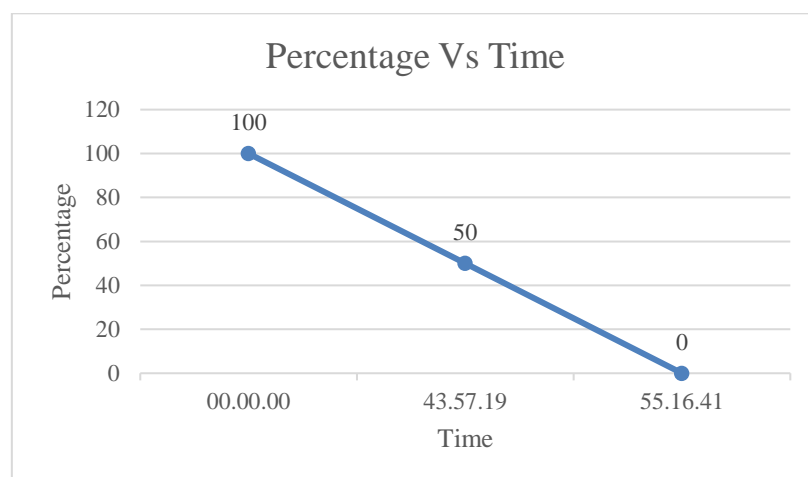


**Figure 4.12 Graph percentage vs time monitoring test 2**

### Testing monitoring and response 3

**Table 4.11 Testing monitoring and response 3**

Time	Impact	Response
00.00.00	High	Work greatly with full power of thrusters
43.57.19	Medium	Slow response from RC receiver and thruster work on low speed
55.16.41	Low	Thruster did not accept response from receiver and led indicator on RC receiver slowly fade. (receiver also depends on battery)



**Figure 4.13 Graph percentage vs time monitoring test 3**

The line graph shows that average time from 100% battery to 0% battery. From the results of 3 testing, it can be concluded that, 2200mAh LiPo battery can run up below 60 minutes since the battery operate three (3) thrusters and one (1) servo motor at one time. Time under 60 minutes is an excellent time for a small underwater robot vehicle since this is for education purpose. The battery must to be charged in order to use the ROV again.



## CHAPTER 5

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 Conclusion

The project that has been tested meets the objectives of the good achievements. The data collected has been well observed and studied in relation to the theory and experimented with data to small-scale ROV to run. The first objective is to design a concept of a small-scale power module of ROV that suitable for education purpose by using engineering design methodology, morphological chart and conceptual design method helps to identify engineering criteria with the concern of product requirements.

The second objective is to fabricate the small-scale ROV that suitable for education purpose. The design of power module consisted of internal component such as batteries, electrical board part and motor controller. The ROV frame using Nylon material and housing for power module, Polypropylene material has been used instead of 3D printed that will make the ROV heavy and did not meet the requirement.

The third objective is to investigate the buoyancy and power needed for small-scale ROV. There are 2 things to investigate and need brainstorming. For buoyancy, there are many methods used to identify whether the material is safe to use. since all electrical components are in the housing, its priority is waterproof and can dive for a long time. Based on this investigation, the use of air tight container is the right choice as it is light and easy to use. however, much needs to be emphasized when using this material especially on the holes that have been drilled for the wire exit passage to the thruster and grabber. The best sealing is very important for this housing as well as constant monitoring to ensure all components are in good condition.

For power, the calculation and use of components should research carefully as this will cause the thruster to not be able to function. the brushless thruster used is not the same as the brushed thruster and the motor controller must be in accordance with the selected thruster. With just the use of one 11.1V battery, our small-scale ROV is able to run without any interference. It's just that it can't be used for a long time when diving.

## **5.2 Recommendations**

There are few recommendations are provided to improve the power module system. Since now this small-scale ROV only using simple method to operate which is using a RC control, this might be easy to use and easy to calibrate. Changing a system of the ROV to operate might be better so the ROV thrusters can reverse and driving respectively dive on any axis. By adding another thruster to dive, it will further increase the power of this ROV, to continue diving with fast time. The appropriate better experience ROV is using 4 thrusters. Moreover, using other type of thruster also can be useful since using motor controller combines with Raspberry Pi or Aduino might be better do make fully operating and maximize the potential of the ROV.

Lastly, select the batteries that has long time power and able to work and operate for a long time. Since the thruster have 12-24V, the battery was not compatible and does not operate with the highest power. Additionally, one pack 11.1V LiPo battery supplied to 3 thrusters and 1 servo motor at the same time. then, the power given is not at the highest level. 14.8V LiPo battery is the best option if it had to change it. Two (2) LiPo batteries to control 4 thrusters are very suitable and the ROV can operate at full speed, in at the same time, can dive for a very long time.

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## APPENDICES

### APPENDIX A Process of building small-scale ROV.

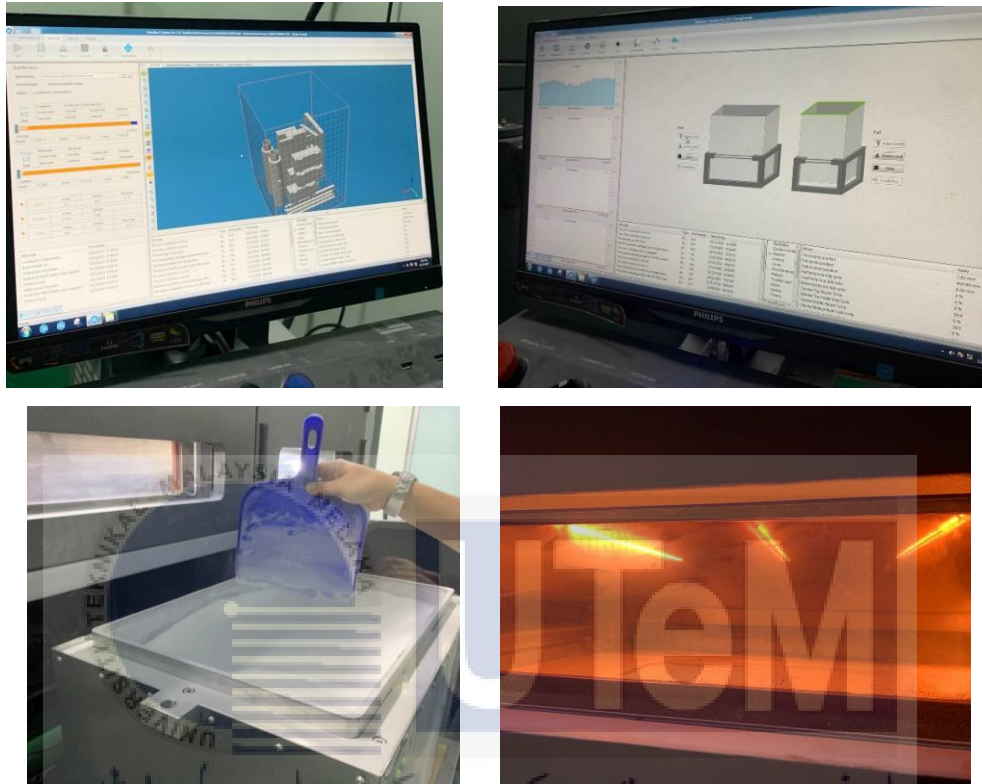
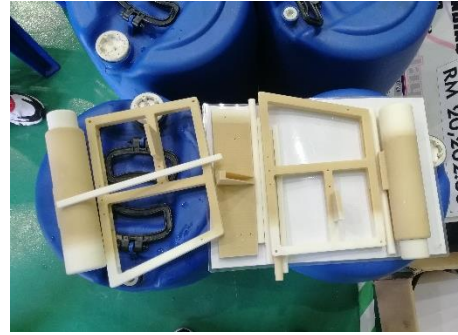


Fig. Process of arrangement for 3D printing SLS machine

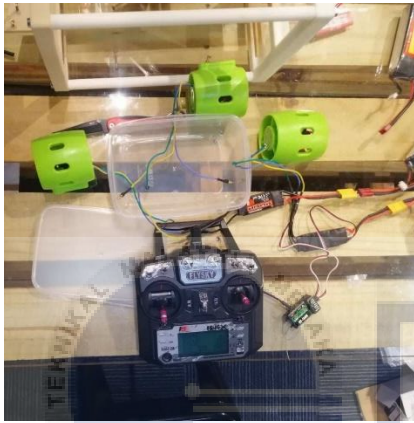
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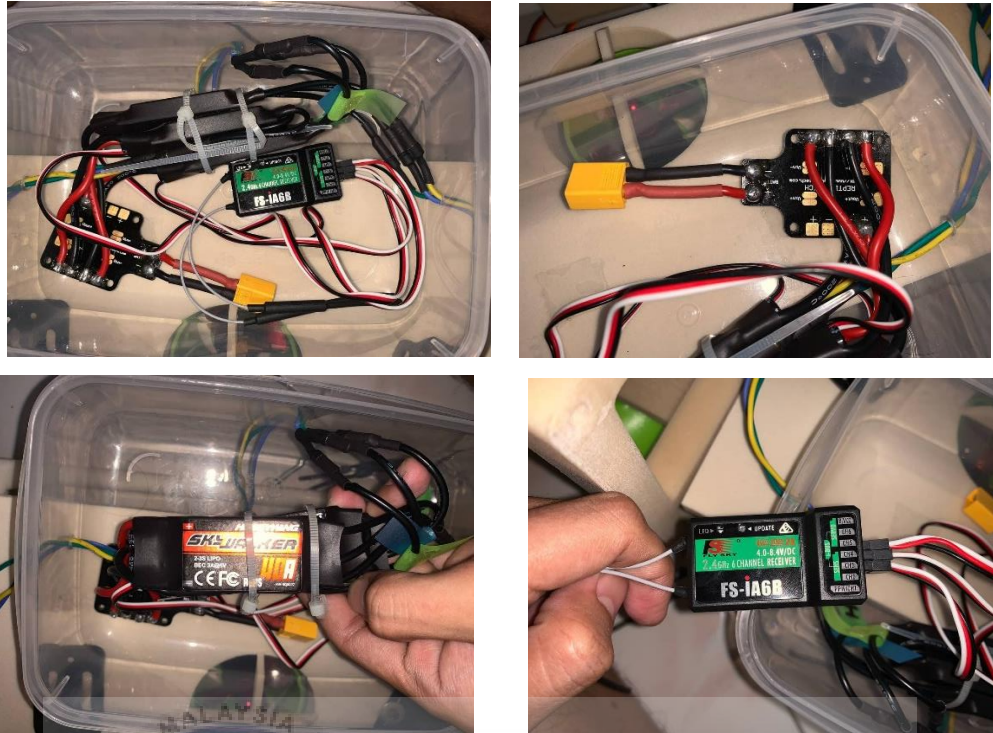




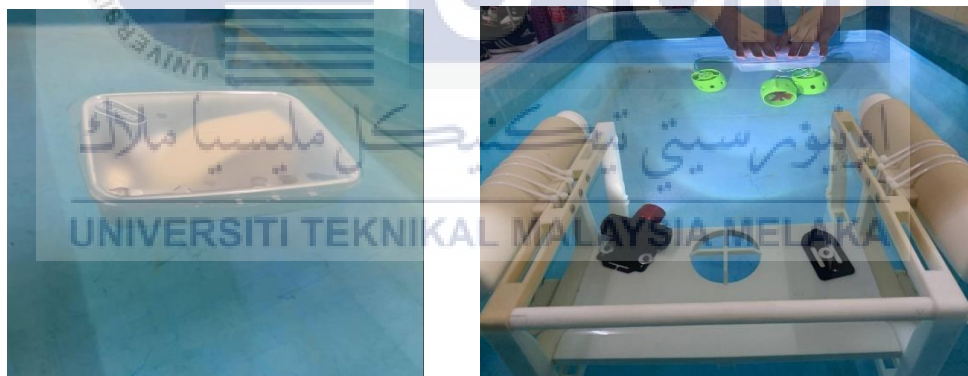
**Fig. Process of cleaning**



**Fig. Process of calibrating and installing electrical component**

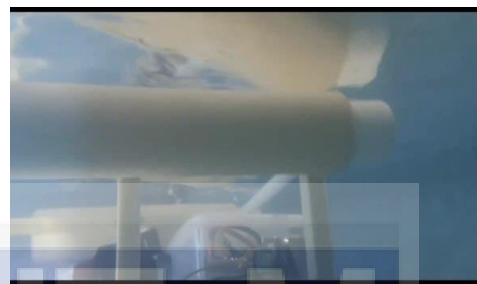


**Fig. Arrangement of electrical component**

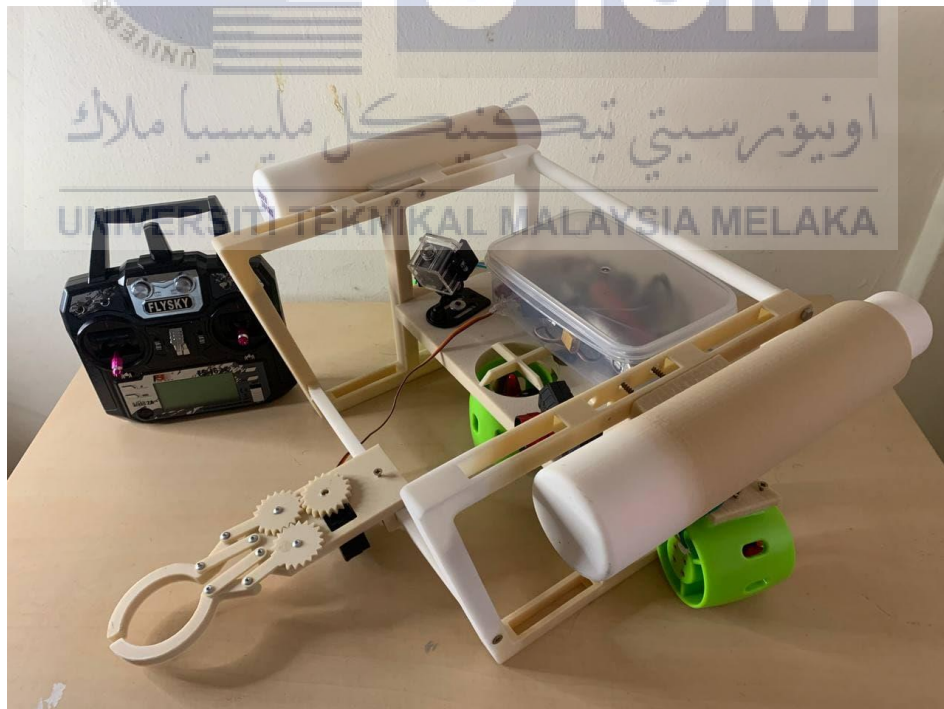


**Fig. Buoyancy testing and improvements**





**Fig. Footage small-scale ROV diving and driving in tub of water**



**Fig. Small-scale ROV**

## APPENDIX B Analysis Data Report on Power Module Housing

Mass	0.154346 kg
Area	156930 mm <sup>2</sup>
Volume	171686 mm <sup>3</sup>
Center of Gravity	x=-114.426 mm y=-66.9599 mm z=-77.9685 mm

Note: Physical values could be different from Physical values used by FEA reported below.

### Static Analysis:1

#### General objective and settings:

Design Objective	Parametric Dimension
Study Type	Static Analysis
Last Modification Date	15/1/2022, 8:52 PM
Detect and Eliminate Rigid Body Modes	Yes
Separate Stresses Across Contact Surfaces	Yes
Motion Loads Analysis	No

#### Mesh settings:

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

### Material(s)

Name	Polypropylene	
General	Mass Density	0.899 g/cm <sup>3</sup>
	Yield Strength	30.3 MPa
	Ultimate Tensile Strength	36.5 MPa
Stress	Young's Modulus	1.34 GPa
	Poisson's Ratio	0.392 ul
	Shear Modulus	0.481322 GPa
Part Name(s)	ContBase_Part.ipt ContCover_Part.ipt	

### Operating conditions

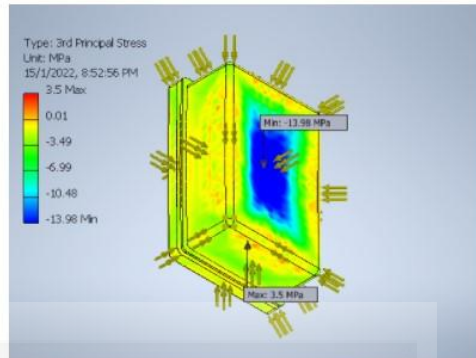
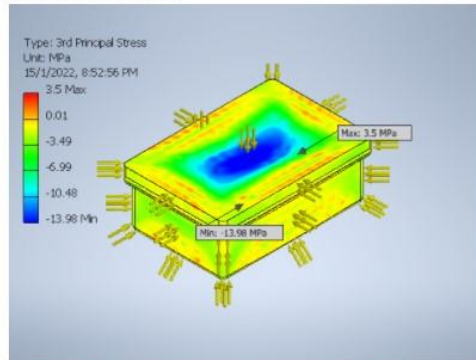
#### Pressure:1

Load Type	Pressure
Magnitude	0.020 MPa



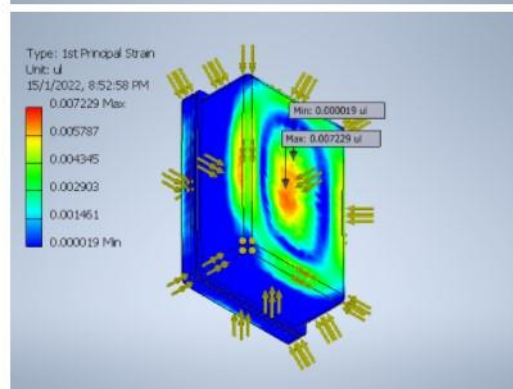
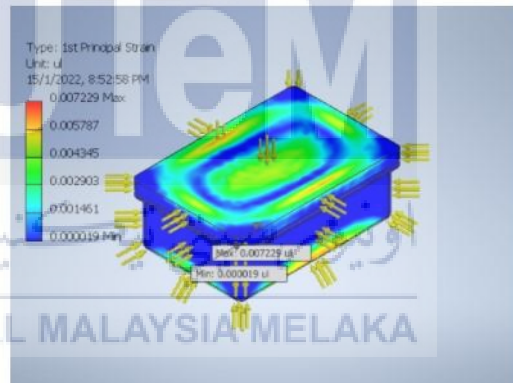
### 3<sup>rd</sup> principle Stress

#### 3<sup>rd</sup> Principal Stress



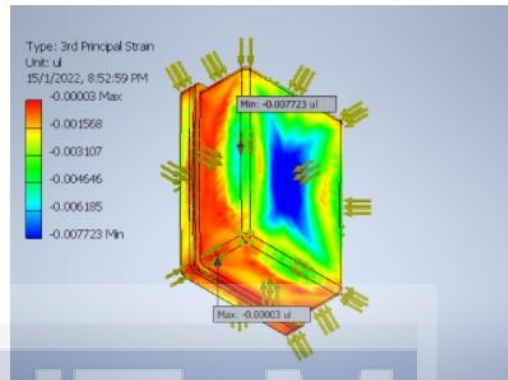
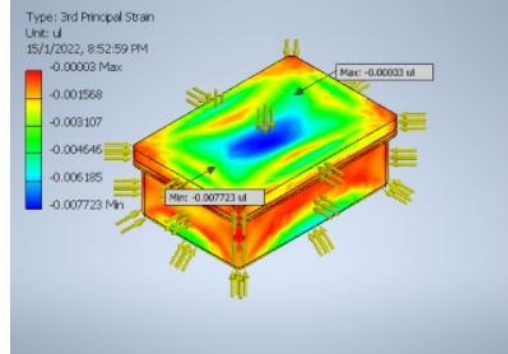
### 1<sup>st</sup> principle Strain

#### 1<sup>st</sup> Principal Strain



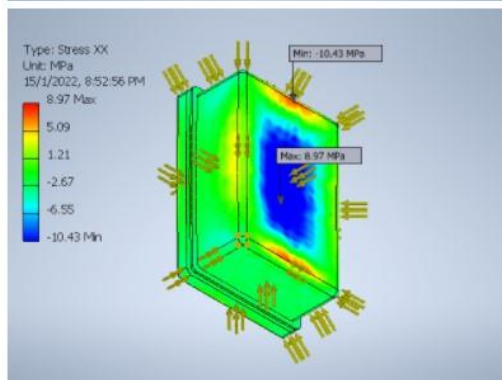
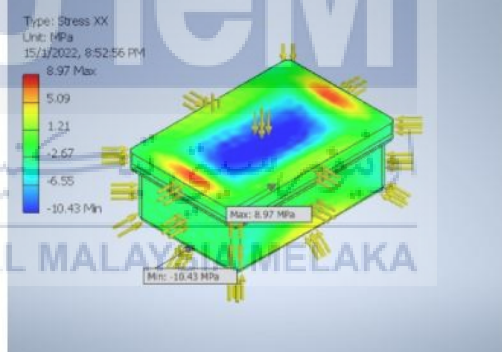
### 3<sup>rd</sup> principle strain

#### 3<sup>rd</sup> Principal Strain



### Stress XX

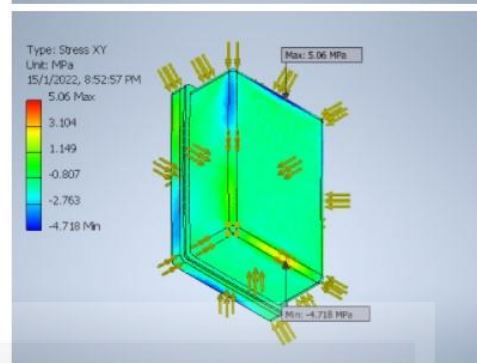
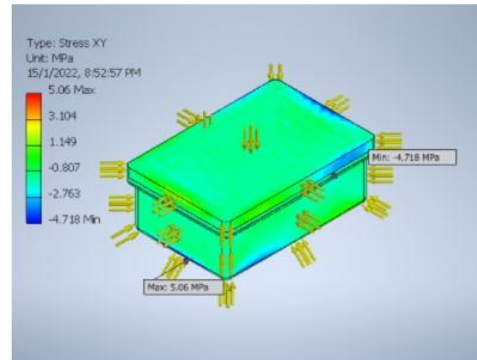
#### Stress XX





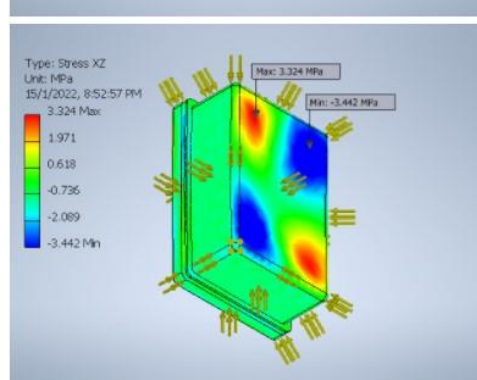
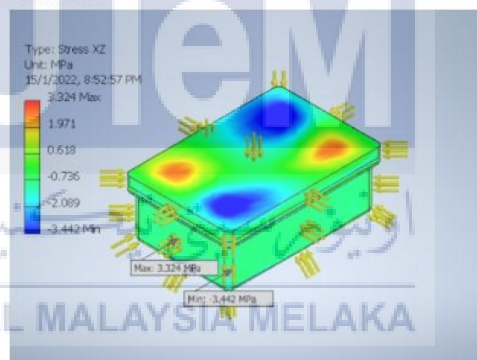
## Stress XY

### Stress XY



## Stress XZ

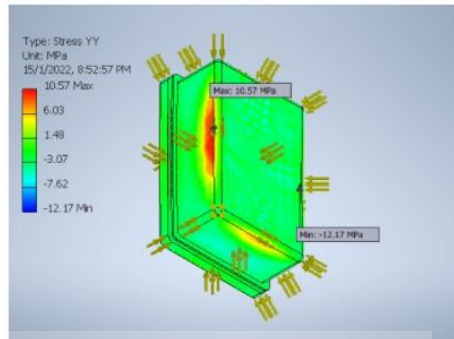
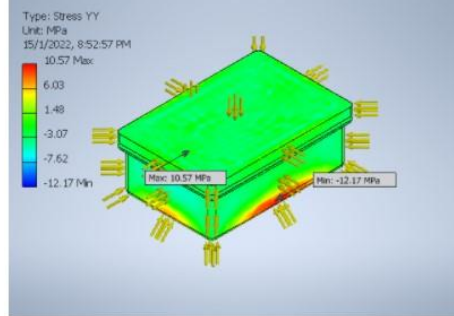
### Stress XZ





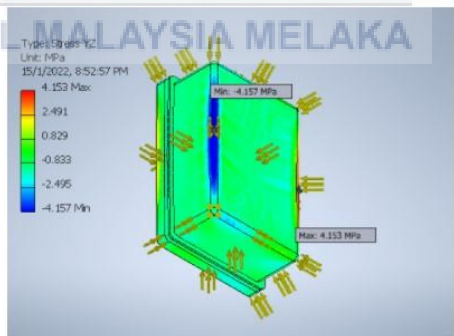
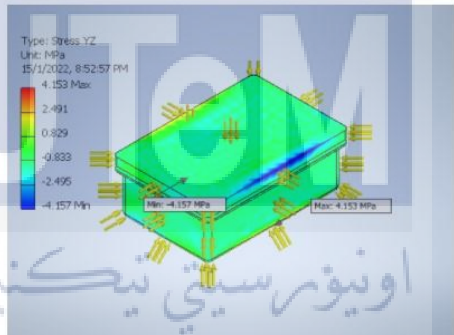
## Stress YY

### Stress YY



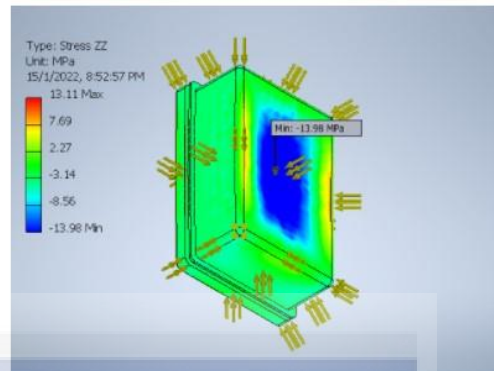
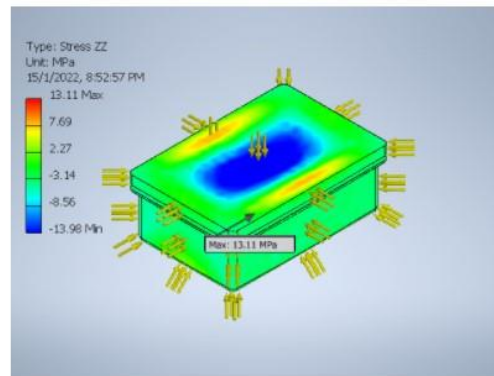
## Stress YZ

### Stress YZ



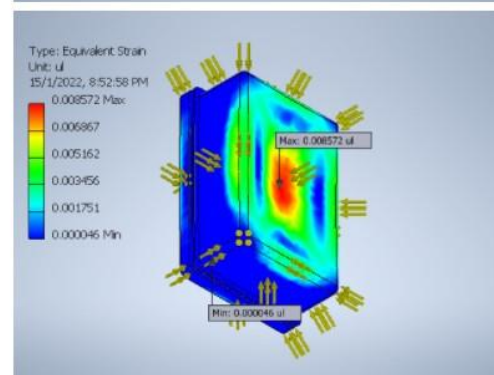
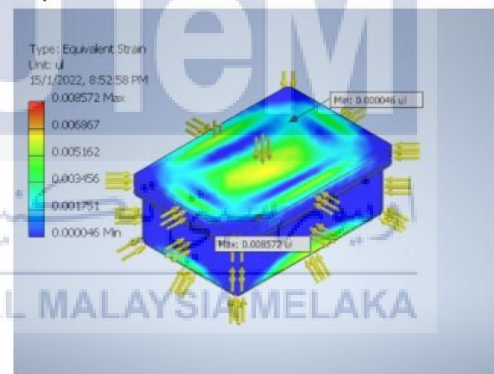
## Stress ZZ

### Stress ZZ



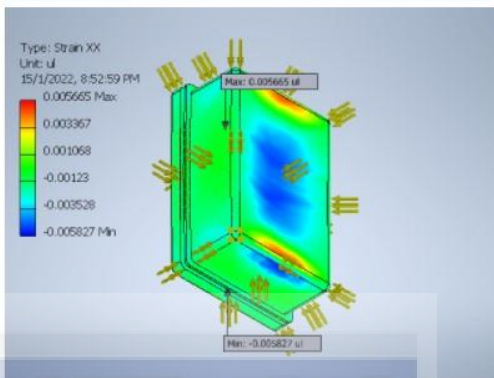
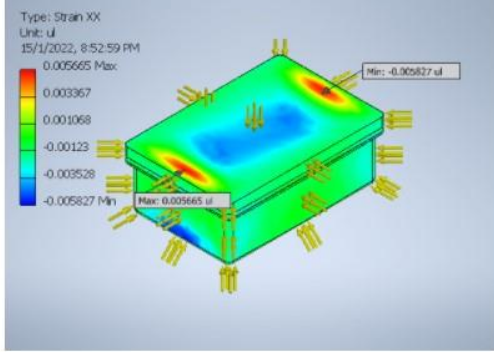
## Equivalent strain

### Equivalent Strain



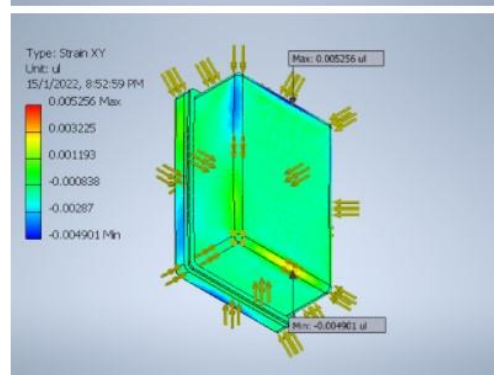
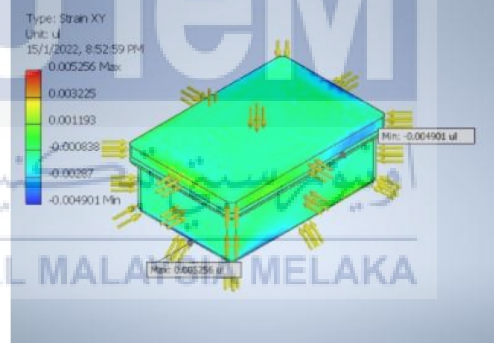
## Strain XX

### Strain XX



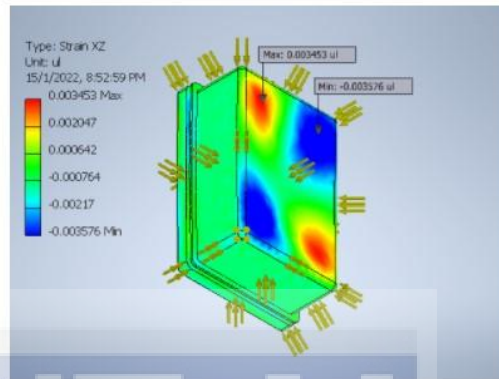
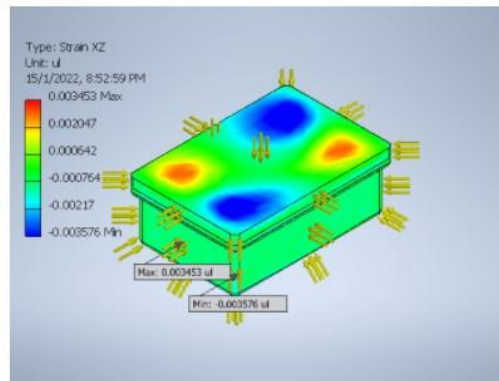
## Strain XY

### Strain XY



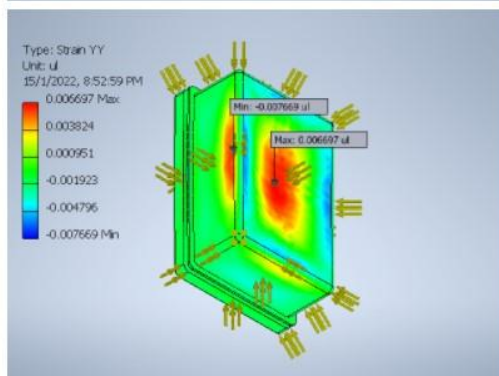
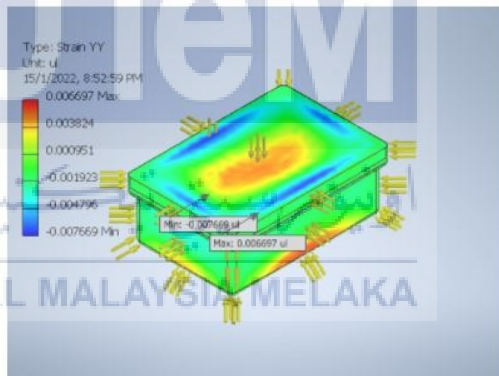
## Strain XZ

### Strain XZ



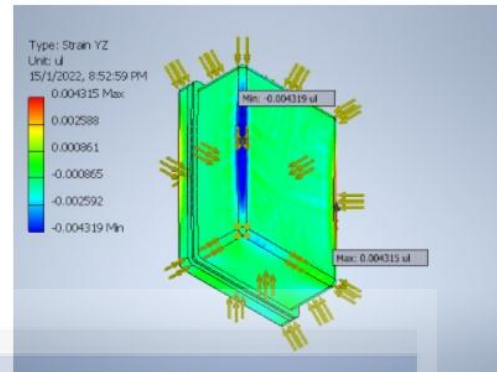
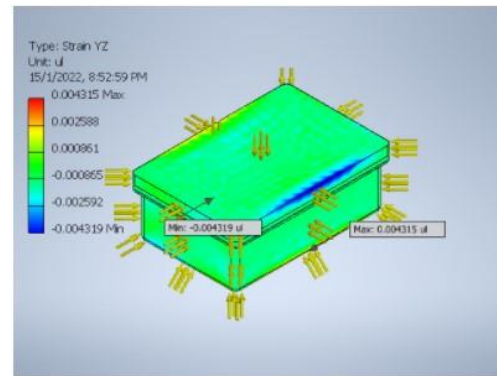
## Strain YY

### Strain YY



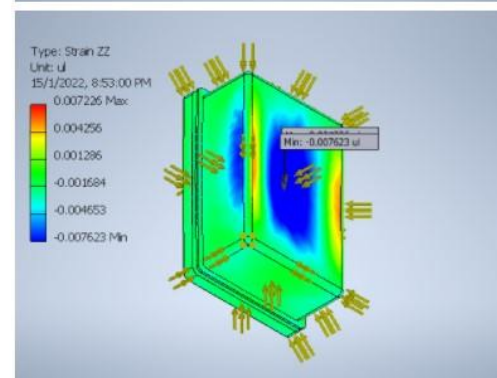
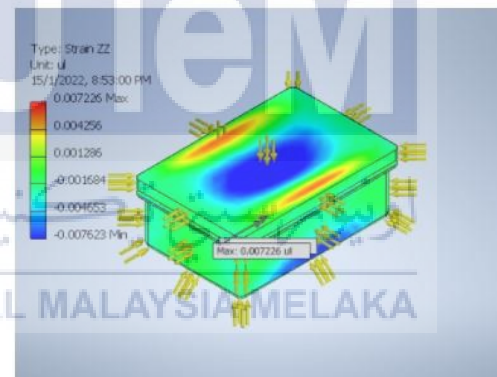
## Strain YZ

### Strain YZ

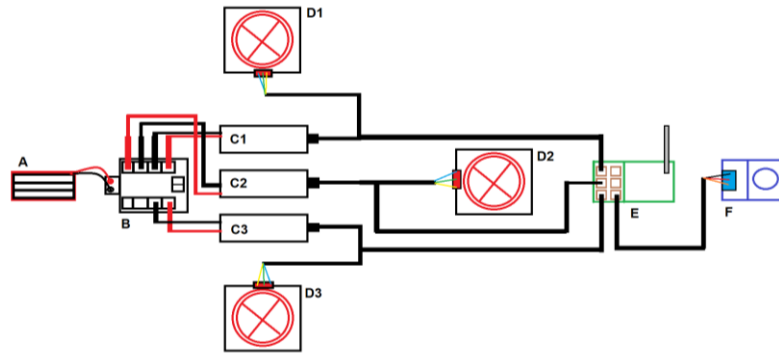



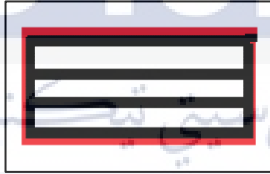
## Strain ZZ

### Strain ZZ

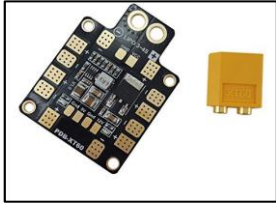
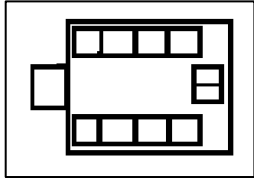




## APPENDIX C Description of Product Specification for Small-scale ROV




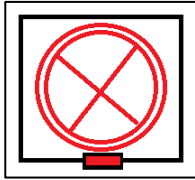
Component A: Lithium Polymer (LiPo) battery	
<b>Component Image</b>	
<b>Component Symbol</b>	
<b>Description</b>	<p>A lithium polymer battery</p> <ul style="list-style-type: none"> <li>• Ordinary Voltage: 11.1V</li> <li>• Fully-charge Voltage: 12.6V</li> <li>• Capacity: 2200mAh</li> <li>• Discharge rate: 30C</li> <li>• Able to use for most of the 12V controllers, motors or any other appliances</li> <li>• Must charge with designated LiPo Battery Charger</li> <li>• Dimension: 105mm x 33mm x 21mm</li> </ul>
<b>Connection towards system</b>	Provide power as voltage towards the ESC and the power up the thruster as well as the servo
<b>Functionality</b>	Provided with higher specific energy than other lithium battery types and are in application where weight is critical feature, such as mobile devices, radio control aircraft and more electric vehicle


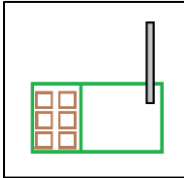


Component B: Power Distribute Board (PDB)	
Component Image	
Component Symbol	
Description	<p>Power Distribute Board</p> <ul style="list-style-type: none"> <li>• General Input voltage range (3S-4S LiPo operation): 9 - 18V DC and Regulated 5V and 12V outputs</li> <li>• ESC outputs: Continuous current: 25A*4 or 15A*6 and Peak current (10 seconds/minute): 30A*4 or 20A*6</li> <li>• Designed for RC Receivers, Flight controllers, OSD, and Servos.</li> <li>• DC/DC synchronous buck regulator.</li> <li>• Voltage: 5.0 +/- 0.1VDC</li> <li>• Continuous current: 2 Amps (Max.2.5A 10s/minute)</li> <li>• Dimensions: 36 x 50 x 4 mm (without XT60)</li> <li>• Mounting: 30.5 x 30.5mm, <math>\Phi 3</math>mm and Weight: 7.5g(w/o XT60), 11g(w/ XT60)</li> </ul>
Connection towards system	Distribute power or voltage among the 3 ESC respectively
Functionality	Power Distribution Board is a board which allows transferring the power from the battery to ESCs / Motors and generate power supply for the flight controller and other peripherals with different voltage levels. Also, PDB provides the functionality for battery voltage / current measurements

Component C: Electronic Speed Control (ESC)	
Component Image	
Component Symbol	
Description	<p>40A HobbyWing ESC for DJI 2212 Brushless Motor~ (2-3S)</p> <ul style="list-style-type: none"> <li>• Output capability: Continuous current 40A, short-time current 55A (less than 10 seconds);</li> <li>• Power input: Section 2-3 5-9 Li-ion battery pack or a nickel hydrogen / nickel cadmium batteries;</li> <li>• BEC Output: 5V @ 3A (linear regulator mode -linear mode);</li> <li>• Maximum speed: 210000 2-pole motor rev / min, 6-pole motors 70,000 rev / min, 12 pole motors 35,000 rev / min;</li> <li>• Size: 68mm (length) * 25mm (width) * 8mm (high) and Weight: 39g</li> </ul>
Connection towards system	Supply power towards the Thruster in adjustable speed of the component
Functionality	<p>Mostly the rapid speed of the motor being use will then minimize where it can be maximize again using the transmitter where it will connected to control using viable arial to get the connection running. The motor itself will emits it characteristic high-pitched whine, especially noticeable at lowering the speed</p>



Component D: Brushless Underwater Thruster	
Component Image	
Component Symbol	
Description	<p>Brushless Underwater Thruster</p> <ul style="list-style-type: none"> <li>• Weight: 130g/pc</li> <li>• Voltage: DC 12V-24V</li> <li>• Current: 20A</li> <li>• KV: 1000KV</li> <li>• Power: 30-200W</li> <li>• Wire length: 250mm</li> <li>• Whole length: 75mm</li> <li>• Propeller diameter: 62mm</li> <li>• Hole diameter: 2.3mm</li> <li>• Steel ball bearing and aluminium alloy</li> </ul>
Connection towards system	Control the manoeuvrability of the Mini ROV from the transmitter and follow every command it receive from the controller
Functionality	A brushless DC motor is essentially flipped inside out, eliminating the need for brushes to flip the electromagnetic field. In brushless DC motors, the permanent magnets are on the rotor, and the electromagnets are on the stator. A computer then charges the electromagnets in the stator to rotate the rotor a full 360-degrees.

Component E: Receiver	
Component Image	
Component Symbol	
Description	<p>Receiver Brand: Flysky</p> <ul style="list-style-type: none"> <li>• Item Name: FS-iA6B with Channel: 6</li> <li>• Frequency Range: 2.4055--2.475GHZ and Band Width Number: 140</li> <li>• Transmitting Power: <math>\leq 20\text{dBm}</math></li> <li>• Antenna Length: 26mm * 2 (dual antenna)</li> <li>• Input Power: 4.0-6.5V DC</li> <li>• Dimension: 47 x 26.2 x 15mm and Weight: 14.9g</li> </ul>
Connection towards system	Transmit the connection from the controller following the command that were given. The receiver is fixed within the signal and constantly receives signals from the transmitter, in our cases, it controls the esc which then control the thruster
Functionality	When a transmission is identified, it translates the number of electrical pulses into action

Component F: High Torque Servo motor	
Component Image	
Component Symbol	
Description	<p>Model: TowerPro Servos MG996R</p> <ul style="list-style-type: none"> <li>• Working Frequency: 20ms period / 50hz (Digital Control)</li> <li>• (RX) Required Pulse: 3.0 ~ 5 Volt Peak to Peak Square Wave</li> <li>• Operating Voltage: 4.8 ~ 6 V DC Volts</li> <li>• Operating Temperature Range: 0 to + 55 Degree C</li> <li>• Operating Speed (4.8v): 0.200 sec/60° degrees at no load</li> <li>• Operating Speed (6v) 0.160 sec/60° degrees at no load</li> <li>• Stall Torque (4.8v): 9.4kg/cm</li> <li>• Stall Torque (6v): 11kg/cm</li> <li>• Motor Type: Brushed Motor</li> <li>• Potentiometer Drive: Direct Drive</li> <li>• Bearing Type: Output Bearing</li> <li>• Gear Type: Brass &amp; Aluminum Gears</li> <li>• Case Material: Plastic</li> <li>• Programmable: NO</li> <li>• Connector Wire Length: 32.0cm (12.6 inch)</li> <li>• Dimensions: 40.7×19.7×42.9mm</li> <li>• Weight: 55 grams (2.64 oz)</li> </ul>
Connection towards system	Move the grabber following the command from the transmitter which is the controller
Functionality	A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback.

# APPENDIX D Cost Analysis

Product	Quantity	Price	Total Cost
JJRC1 12 -24 V 20A Brushless Motor 4 Blade	3	RM58.67	RM176
Waterproof Camera Sport Camera SQ29	1	RM50.59	RM50.59
Battery 11.1V 2200mAh LiPo Rechargeable Battery	1	RM75	RM75
Air Tight Food Keeper E-1632 1000 ML	1	RM4.90	RM4.90
FLYSKY 16X Transmitter (RC Remote Controller) Price including FSIA6B Receiver	1	RM240	RM240
HOBBYWING SKYWALKER 40A ESC	3	RM50	RM150
PDB- 006 35 X 35	1	RM5	RM5
XT60 STANDARD	1	RM4	RM4
USB HEADLIGHT BL-8102	1	RM15.70	RM15.70
MG946R METAL GEAR SERVO	1	RM29	RM29
<b>TOTAL</b>			<b>RM750.19</b>

**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA**

**TAJUK: DEVELOPMENT OF POWER MODULE OF SMALL-SCALE ROV FOR EDUCATIONAL PURPOSE**

**SESI PENGAJIAN: 2021/22 Semester 1**

Saya **MOHD SHAFIQ NAZRI BIN KUSSIM**

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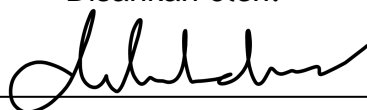


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Tarikh: 18/01/2022

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**Tajuk Tesis: DEVELOPMENT OF POWER MODULE OF SMALL-SCALE ROV FOR EDUCATIONAL PURPOSE**

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Sekian, terima kasih.

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