DESIGN AND ANALYSIS OF UNMANNED SURFACE VEHICLE INSTRUMENT FOR PHYTOPLANKTON DETECTION

MUHAMMAD HISYAM BIN AZMAN

B.ENG (HONS.) MECHATRONICS ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name	:	**MUHAMMAD HISYAM BIN AZMAN**
Identification Card No	:	**920205-06-5561**
Title	:	**DESIGN AND ANALYSIS OF UNMMANNED SURFACE VEHICLE INSTRUMENT FOR PHYTOPLANKTON DETECTION**
Academic Session	:	**2015/2016**

I declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☐	**OPEN ACCESS**	I agree that my thesis to be published as online open access (Full text)

I acknowledge that Universiti Malaysia Pahang reserve the right as follows:

1. The Thesis is the Property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_____	_____
(MUHAMMAD HISYAM BIN AZMAN)	(PROF. DR. ZAHARI BIN TAHA)
Date: _____	Date: _____

DESIGN AND ANALYSIS OF UNMANNED SURFACE VEHICLE FOR PHYTOPLANKTON DETECTION

MUHAMMAD HISYAM BIN AZMAN

Report submitted in partial fulfillment of the requirements
for the award of the degree of
B.Eng (Hons.) Mechatronics Engineering

Faculty of Manufacturing Engineering

UNIVERSITI MALAYSIA PAHANG

JUNE 2016

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of Degree of Mechatronics Engineering.

Signature :

Name of Supervisor : PROFESSOR DR. ZAHARI BIN TAHA

Position : SENIOR LECTURER

FACULTY OF MANUFACTURING ENGINEERING

UNIVERSITI MALAYSIA PAHANG

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :

Name : MUHAMMAD HISYAM BIN AZMAN

ID Number : FB11046

Date :

Dedicated to my family,

Azman Bin Omar, Nor Hizer Binti Mohd Salleh, Muhammad Khirul Azri, Muhammad Hakim and Muhammad Azam.

Special dedication to my supervisor,

Prof. Dr. Zahari bin Taha

For his dedication and guidance towards my research.

ACKNOWLEDGEMENT

In the name of ALLAH, the Most merciful and the Most compassionate.

Firstly, Alhamdulillah and thanks to Allah SWT for giving me good health, strength and patience in completing my Final Year Project

Secondly, I would like to express my sincere gratitude to my supervisor, Prof. Dr. Zahari Bin Taha and my mentor Mr. Jessnor Arif Bin Mat Jizat for all the help and guidance for my final year project. I am deeply grateful with all the valuable help and supervision throughout the project.

I would like to acknowledge all my friends and all members of Innovative Manufacturing, Mechatronics and Sports Lab (iMAMS) who help me a lot to finish this project. They always support and helped me in a ways that no one can repay.

I also would like to thank my parents for the unceasing encouragement and support during all of the ups and downs of my project. I am very grateful to all my family member. Lastly, I like to place on record, my gratitude to one and all, which directly or indirectly involved in this project. Thank you, everyone.

ABSTRACT

Phytoplankton is the heart of marine ecosystem. It is the basic aquatic food webs and acts as the food provider to marine organisms. Phytoplankton is like normal plant, requires sunlight to perform photosynthesis. It consumes carbon dioxide, releases oxygen and contains chlorophyll. The presence of phytoplankton is essential to form a balance ecosystem. However the phytoplankton can also bring harm. When there is too many nutrients available, phytoplankton may bloom out of control. Uncontrolled phytoplankton blooms can form harmful algal blooms (HABs) and can disturb a balanced marine ecosystem. In conjunction to that, making phytoplankton detection is the first and important step to prevent the harmful algal blooms. The aim of this research project is to develop an instrument that can simplify the way of phytoplankton detection. The main goal of this project is to design and analysis a comprehensive design methodology, implementation and testing of an instrument to be embedded to an unmanned surface vehicle.

ABSTRAK

Fitoplankton adalah nadi ekosistem marin. Ia adalah asas siratan makanan akuatik dan bertindak sebagai pembekal makanan kepada organisma marin. Fitoplankton adalah seperti pokok biasa, memerlukan cahaya matahari untuk melakukan fotosintesis. Ia menyerap karbon dioksida, melepaskan oksigen dan mengandungi klorofil. Kehadiran fitoplankton adalah penting untuk membentuk ekosistem yang stabil. Walau bagaimanapun fitoplankton juga boleh membawa kemudaratan. Apabila terdapat terlalu banyak nutrien, fitoplankton boleh membiak di luar kawalan. Pembiakan fitoplankton yang tidak terkawal boleh membentuk alga berbahaya dan boleh mengganggu ekosistem marin yang seimbang. Sehubungan dengan itu, membuat pengesanan fitoplankton adalah langkah pertama dan penting untuk mengelakkan alga berbahaya.Tujuan penyelidikan ini adalah untuk membangunkan alat yang boleh memudahkan cara mengesan fitoplankton. Matlamat utama projek ini adalah untuk mereka bentuk dan menganalisa metodologi reka bentuk, pelaksanaan dan ujian alat yang menyeluruh untuk diletakkan bersama kenderaan permukaan tanpa pemandu.

TABLE OF CONTENT

CHAPTER 2 LIRERATURE REVIEW

CHAPTER 3 METHODOLOGY

CHAPTER 4 RESULT AND DISCUSSION

CHAPTER 5 CONCLUSION AND RECOMMENDATION

LIST OF TABLE

LIST OF FIGURE

LIST OF FIGURE

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE RESEARCH

Ocean is a very dynamic environment. It covers almost 71 percent of earth's surface and it is divided into 5 areas consisting of Pacific, Atlantic, Indian, Southern, and lastly Artic Oceans. Ocean also holds 97 percent of water on earth and almost 95 percent of part of the ocean remains unexplored. This shows that there are many types of organism and microorganism yet to be discovered.

Earth's system such as climate and weather are heavily affected by the condition of the ocean. The importance of the oceans and the organism live in it has gained some attentions nowadays. In recent years, the need for efficient ocean monitoring has led to the development in acoustic, physical and optical oceanography sensor. The sensor is mainly use for phytoplankton detection. Phytoplankton can be said as the heart of the marine ecosystem and the monitoring of the phytoplankton bloom is very important. It is the key for effective management of oceanic resources.

The phytoplankton bloom is the marine ecosystem health's indicator. The bloom can happen in hundreds of square kilometre under the right conditions. The aforementioned conditions include the availability of carbon dioxide, nutrients and sunlight. Phytoplankton is the foundation of marine food web. Phytoplankton acts as the primary producers and aquatic animals like zooplankton feed on them. The availability of phytoplankton is very important for the whole marine ecosystem.

Nowadays, there are many ways to detect phytoplankton. The traditional methods like flow cytometry, high performance liquid chromatography and microscopy are reliable but also time-consuming and cannot provide in situ measurement. Detection of phytoplankton by using payload scientific instrument like Medium Resolution Imaging Spectrometer (MERIS) and Moderate Resolution Imaging Spectroradiometer (MODIS) is very expensive and not everyone has access to it. Development of instrument that can detect phytoplankton instantly at the research area can bring many advantages to ocean monitoring.

In situ sensor that can detect the phytoplankton is very useful for phytoplankton monitoring. The parameter to detect the phytoplankton needs to be analysed first and then an instrument or multisensory needs to be made.

1.2 PROBLEM STATEMENT

Considerable attention has been focused on the monitoring the phytoplankton in the ocean. It is because phytoplankton plays a very important part in the marine ecosystems. In situ data for phytoplankton detection can provide useful information for science and research purposes. Hence, this research is to develop a new unmanned surface vehicle instrument that can detect phytoplankton in the ocean.

1.3 OBJECTIVES

The main objectives of this project are:

- To analyse the detectability of phytoplankton.
- To develop multisensory for detecting phytoplankton under ocean water surface.
- To integrate other multi sensor for the unmanned surface vehicle, (USV).

1.4 PROJECT SCOPE

This study is focused on designing, fabricating and analysing an instrument for phytoplankton detection. In order to create such instrument, investigation about the in situ phytoplankton detectability has to be done. Parameter on how to detect phytoplankton in various environment need to be studied. An instrument will be developed as an in situ sensor in order to detect phytoplankton. Different water sources such as seawater and pond water will be tested and compared to the sample water that contains actual phytoplankton sample. The results will be compared and analysis will be made to know the detectability of the phytoplankton. The project will be carried out in the laboratory located in Faculty of Manufacturing Engineering, Universiti Malaysia Pahang and in Kuala Pahang area.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss in detail about the phytoplankton detection instrument that needs to be designed for this project as this project is about designing an in situ fluorometer to detect the fluorescence properties of phytoplankton. It also covers the components used to make this instrument. In order to improve the project, some previous researches and projects from many reliable sources will be presented.

2.2 PHYTOPLANKTON

Phytoplankton is defined as algae or microscopic plant. It can be found floating on the surface of water bodies such as lakes, rivers and sea. High concentration of phytoplankton leads to a natural phenomenon known as phytoplankton blooms or algal blooms. The blooms have a very influential relationship with the oceanic primary production as the phytoplankton occupied the base of marine food web.

The most critical process in the primary phytoplankton production is the photosynthesis process. Photosynthesis is the process when phytoplankton converts inorganic substances to organic substances and also converts light energy to chemical

energy. As a result of that, phytoplankton becomes the energy source provider to other marine organisms. 45% of global gross primary productivity is accountable by the algal productivity (Field et al., 1998).

There are many different classes of phytoplankton in the world, but there are two common classes. Dinoflagellate is one of two main classes of phytoplankton. The other one is known as diatoms. Dinoflagellate use flagella, a whip-like tail to move and complex shells are covering their bodies. Meanwhile diatoms do not use flagella. They depends on currents to move through the water. Figure 2.1 presents dinoglagellate features and Figure 2.2 presents diatoms features.

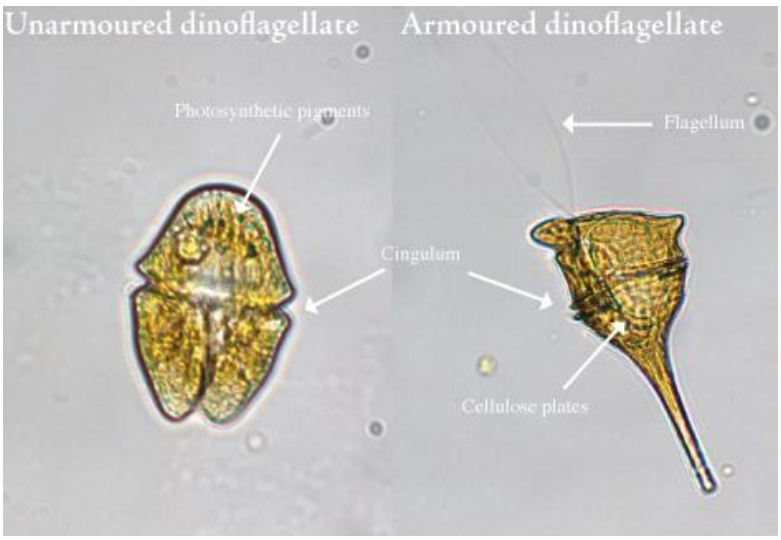

Figure 2.1: Dinoflagellate features

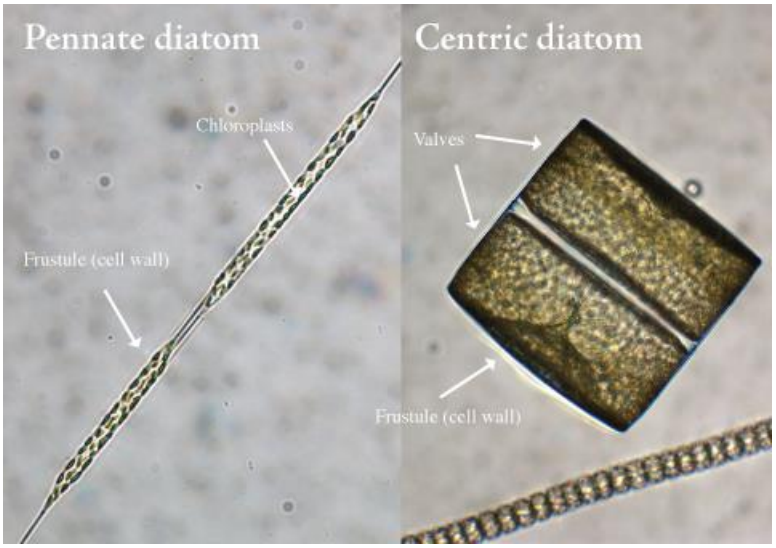

Figure 2.2: Diatoms features

Phytoplankton blooms are detected in many ways. The blooms indicates the marine ecosystem health, thus making the detection is very important tools to monitor the ocean. Phytoplankton bloom can occurs in any place in the open sea. When the conditions like availability of carbon dioxide, nutrients and sunlight are well met, the bloom can occur in large area.

Phytoplankton is important organism because it acts as the primary producer to marine food chain. It is very vital as the energy is transferred to higher organisms through the marine food chain. (Ananthan, G. 2004 and Tiwari,A. 2006).There are two types of phytoplankton bloom. One is not harmful to marine ecosystem and the other one is harmful and bring a lot of damage to marine ecosystem. The harmful phytoplankton is known as red tide. The accumulations of dense phytoplankton until the water turn to appear coloured is the reason why it is called red tide (Lin et.al. 1999). Red tides can affect the environment as well as the tourism industry in the affected region. Thus, ocean scientist, environmental protection department and also the local fishermen have been concerned about the harmful phytoplankton blooms, red tide. (Anderson 1994, 1995).

Red tides is occasionally related to phytoplankton that produce toxins. But it is not a specific term as phytoplankton blooms may happened in brown, grey or colourless. A harmful algal bloom of HABs is more suitable to be referred as the phytoplankton blooms that cause direct or indirect toxic effects to human (Richardson, 1997). HABs can reduce oxygen concentrations and effects marine organisms due to lack of oxygen. When phytoplankton bloom is dominated by harmful algal, toxins released from it can disturb the food web. Human also can be affected from diarrheic shellfish poisoning and paralytic as they consumed affected shellfish (Corrales and Gomez, 1990).

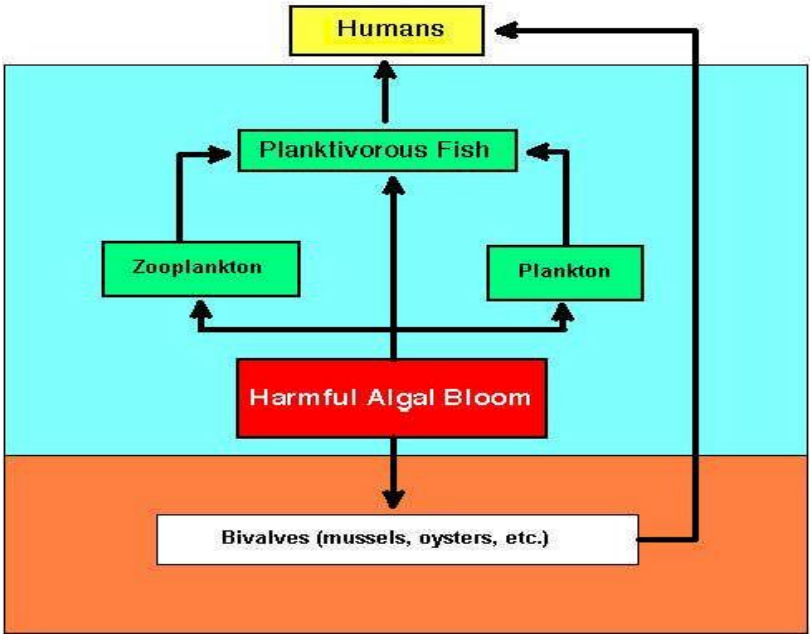

Figure 2.3: Food web of Harmful Algal Bloom, HABs

Source: Universiti Malaysia Sabah, 2005

HABs cause a serious economic problem to countries where fish and other sea animal is one of the main economy resources and protein supplies. Red tide is also one of the reasons why the world sees the development of oceanography sensor and satellite technology.

2.3 PHYTOPLANKTON IN MALAYSIA

There are some researches done about the phytoplankton species exists in Malaysia. Study done in Kuala Sibuti, Miri and Kuala Nyalau, Bintulu Sarawak by A.S.M Saifullah, M.K Abu Hena, M.H Idris, A.R Halimah and I. Johan (2014) shows that the abundance and diversity of phytoplankton were influenced by water quality parameter. The group of phytoplankton found consist of diatom, dinoflagellate, cynophyceae and chlorophyceae species.

There is also a research on the phytoplankton species that is responsible for the red tide incident that occurred in Speanggar Bay, Kota Kinabalu, Sabah by A.Anton, P.L Teoh, S.R Mohd Shaleh and N. Mohammad Noor (2005). The first occurrence of the red tide is observed in January 2005. The species responsible for the harmful algal blooms (HABs) was identified as Cochlodium polykrikoides. Favourable temperature, salinity and nutrient has led to this harmful phytoplankton blooms to occur and caused damages the marine ecosystem nearby.

In May 2011, there is one investigation done from Malacca Strait to South China Sea about phytoplankton and its relationship with environmental factors. The study discovered the phytoplankton there is mainly belonged to diatoms and dinoflagellates classes. The species found there for diatoms class are Pseudo-nitzschia, Thalassionema, Navicula and Skeletonema. Dinoflagellates class represented by species of Scrippsiella, prorocentrum and nano-dinoflagellate. (Zhixin Ke et al., 2011).

2.4 UNMANNED SURFACE VEHICLE INSTRUMENT

Unmanned surface vehicle instrument is designed to make people work easier in a difficult working area. Historically, the detection of phytoplankton and measurement of phytoplankton parameter is primarily in situ but using manpower. Mostly the previous researches using non-opening/closing phytoplankton net (Fraser, 1966) or bongo net (M. Murphy et al. 1980) to collect plankton sample. Then the sample will be tested in vitro with equipment like microscope. This type of sampling and measuring system takes time to produce result.

Figure 2.4: Bongo net use to collect plankton sample.

Source: M. Murphy et al. (1980)

The need for efficient ocean monitoring has led to development of in situ sensor. In situ detection is very efficient in giving fast result and quick reaction if the bloom is dangerous to marine ecosystem nearby.

2.5 PHYTOPLANKTON DETECTION

There are some parameters to detect the phytoplankton. In 1966, Lorenzen introduced the measurement of chlorophyll *a* in vivo fluorescence to monitor the changes in phytoplankton biomass. He measured in vivo chlorophyll concentration from the fluorescent intensity of seawater. Since then, the development of technology to measure changes in phytoplankton biomass using the measurement of chlorophyll *a* has growing rapidly.

Nowadays, there are many commercialize instrument and sensor that has been produced. Commercial benchtop and in situ instruments like fluorometer, radiance and flow cytometers are available in the market. The development has reached the level where the phytoplankton blooms and change in biomass can be observed remotely from an aircraft or satellite.

Medium Resolution Imaging Spectrometer (MERIS) and Moderate Resolution Imaging Spectroradiometer (MODIS) (Yongmin Kim et al. 2009) are two current instruments that can detect sea surface chlorophyll *a* fluorescence from satellite. (Yongmin Kim et al. 2009) .This shows how phytoplankton plays main part in the ecosystem. Now, chlorophyll *a* fluorometry is the main tool for biological oceanography especially for mapping the spatial distribution of phytoplankton at various scales, and for monitoring temporal fluctuations in phytoplankton biomass.

This project will focus on the detection of phytoplankton based on the fluorescent properties of chlorophyll *a*, Chl *a* contained inside the phytoplankton cell. The instrument designed for this project will based on the fluorometer principle.

2.6 CHLOROPHYLL *a*

Chlorophyll *a*,(Chl *a*) is the most common and predominant in photosynthetic organisms such as plants and algae. The molecular formula for chlorophyll *a* is $C_{55}H_{72}O_5N_4Mg$.

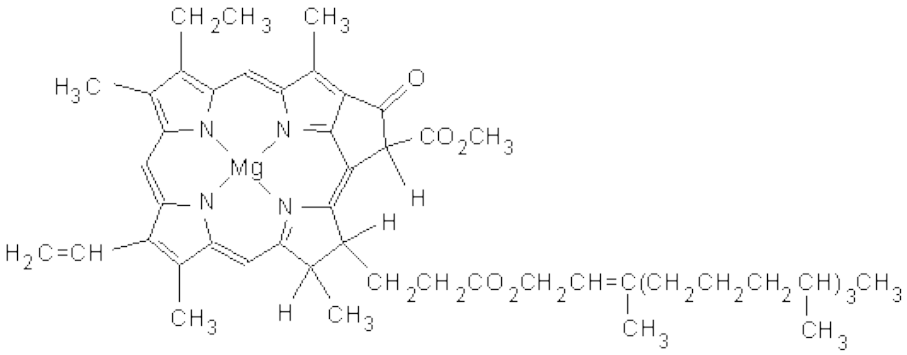

Figure 2.5: Molecular structure of Chlorophyll *a*

Source: Douma (2008).

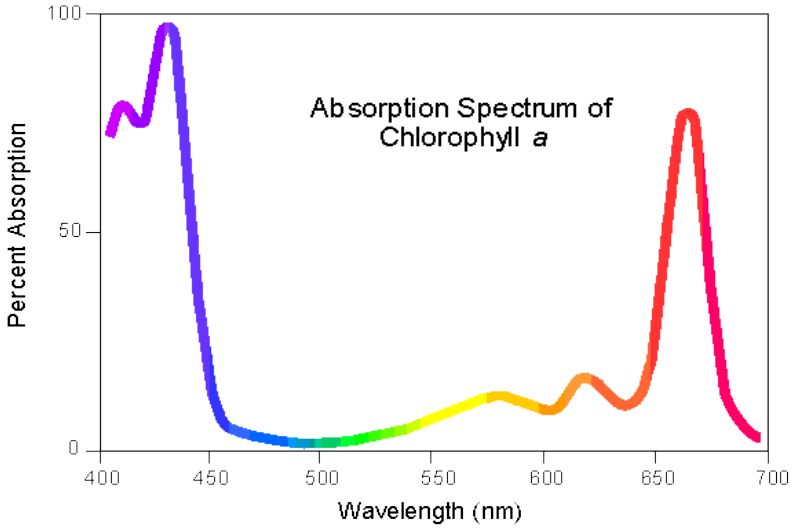

Figure 2.6: Graph of absorption spectrum of chlorophyll a

Source: Schirber (2013)

It is very important for most organisms that perform photosynthesis to release chemical energy. Chlorophyll *a* absorbs light in the blue and red section of the visible electromagnetic spectrum. The blue absorption section band is centred at 430nm meanwhile the red absorption section band is centred at 662nm (Babin M. 2008).

2.7 FLUOROMETER.

Fluorometer or sometimes flourimeter is a device or instrument to detect and measure parameter of fluorescence. It is a type of spectrometer designed to measure the intensity and wavelength distribution of fluorescence.

The fluorescence need to be excited from a certain spectrum of light to be detected by fluorometer in parameter of intensity and wavelength distribution of emission spectrum. In situ fluorometer is used to provide deep-resolved estimation of the phytoplankton biomass (Thomas Leeuw et al. 2013).

Commercial manufactured fluorometer is expensive and makes them hardly available to students and researchers. The initiative to develop low cost fluorometer with simple component has increase. For example Thomas Leeuw et al. and Geoffrey G. Schofield have managed to design and build and in situ fluorometer using low cost electronics.

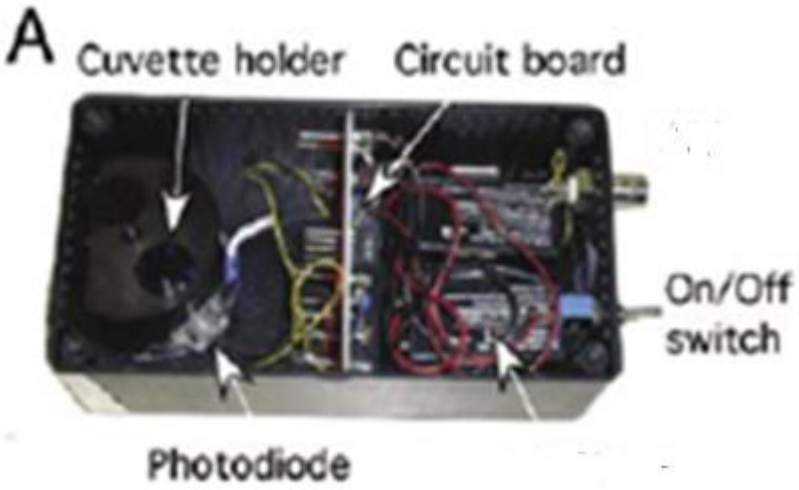

Figure 2.7: Low cost in situ fluorometer by Geoffrey G. Schofield, 2004.

Source: Geoffrey G. Schofield (2004)

Development of in situ fluorometer has increases within the year. Advance in technology has allowed the fluorescence of chlorophyll *a* to be measure from satellite or aircraft. The technology to measure fluorescence is called MODIS, Moderate-Resolution Imaging Spectroradiometer. However, it has a limitation where it can only function during the daylight hours. To measure high resolution measurement of chlorophyll *a*, Chl *a* it requires a submersible instrument. Thus making any submersible in situ fluorometer designed today important to researchers.

2.8 FLUORESCENCE

Emission of light by any substance that absorbed electromagnetic radiation or light is called fluorescence. This is the parameter measured by the fluorometer. The basic working principle to measure the fluorescence properties.

2.8.1 Fluorescence Excitation

Measurement of phytoplankton abundance is simple due to fluorescent properties of chlorophyll a. the chlorophyll a contain inside the phytoplankton cell and have the maximum absorption near 440nm and maximum fluorescence near 685nm. (Babin M. 2008).There are some components that can excite the fluorescence inside the phytoplankton. For example Pengfei et al. use XLamp XR-C Blue, XLamp XR-C Green, and XLamp XR-C Amber as their excitation light sources. The LEDS emits light with different wavelength. Geoffrey G. Schofield in his research in 2004 uses Blue LED HLMP-CB15 as the light exciter. This LED emits 472nm typical dominant wavelength. (Geoffrey G. Schofield, 2004)

2.8.2 Fluorescence Measurement

Fluorescence is a reliable proxy to measure phytoplankton mass. It is because it has unique wavelength of fluorescence which is 685nm and the spectral distance between excitation and emission wavelengths. (Lorenzen, 1966). The fluorescence can be measure using component like photodiode and photomultiplier. The fluorescence excited from the phytoplankton is collected using convex lens and focus to the photodiode or photomultiplier. Then, the photodiode or photomultiplier will produce current based on the intensity of the fluoresced light (Thomass Leeuw et al. 2013).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discuss on the methods used to carry out this research. The main objective is to describe the design and the system used in making the unmanned surface vehicle instrument for phytoplankton detection. The procedure in carrying out this research is to design an instrument that is made by using the principle of design and fabricating a fluorometer. The design consists of hardware part which is the casing of the instrument and the software part where it involves the programming for the Arduino Uno and the data logger.

3.2 PROJECT FLOW CHART

A flowchart in figure represents the methods used for gathering data and information

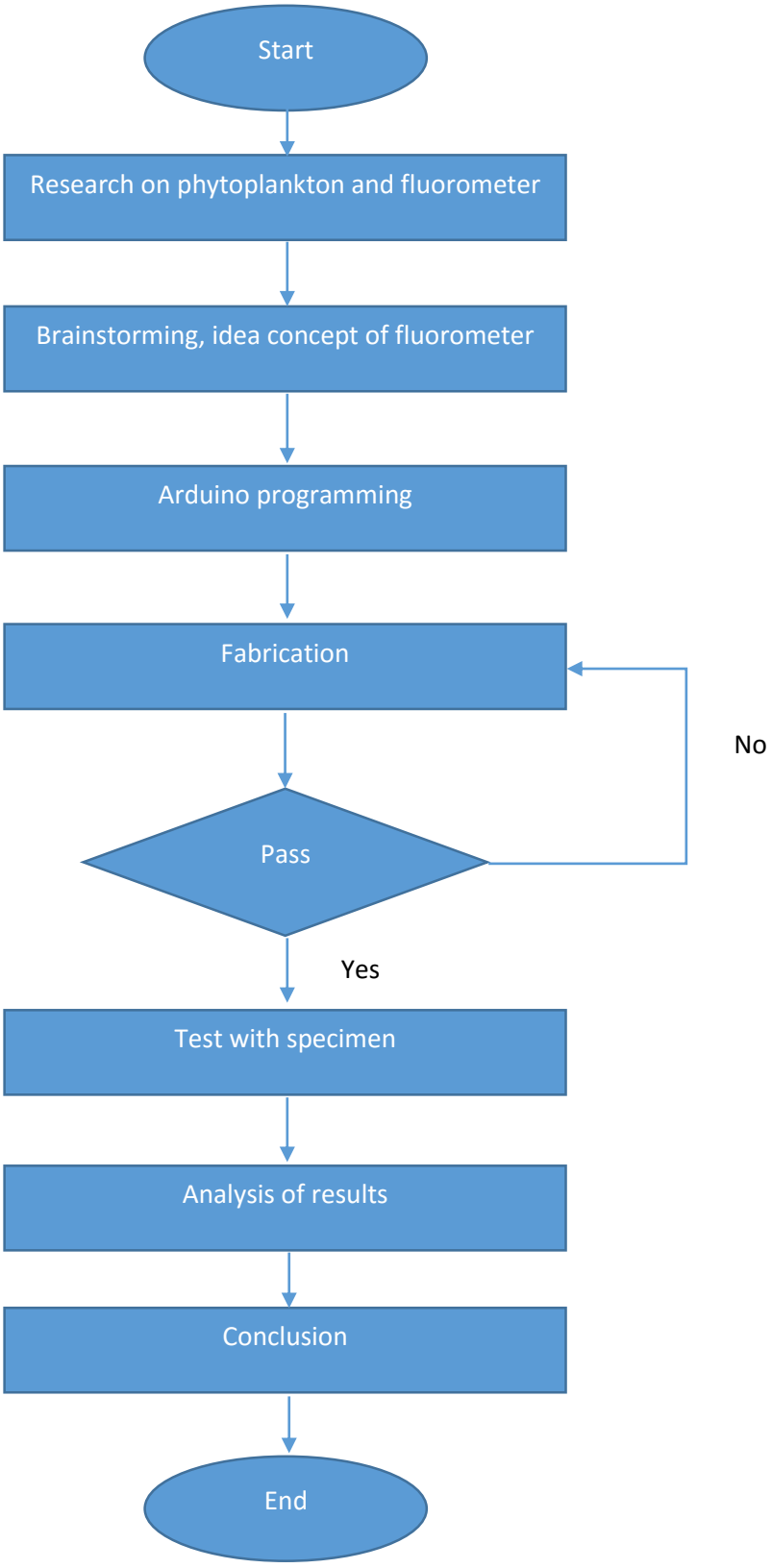

Figure 3.1: Methodology flow chart

3.2 FLUOROMETER WORKING PRINCIPLE

A fluorometer is an instrument that measures the fluorescence as the parameter. Basically, a fluorometer has three instrumentations. The instruments are the light source, light filters and the detectors.

Phytoplankton cells contain chlorophyll a that has a unique fluorescent property. That property enables the phytoplankton to be detected and the phytoplankton biomass to be determined by a fluorometer. The light source is the phase where the fluorometer excites the fluorescence in the chlorophyll a. The light source may be LED's, mercury vapour lamps, xenon arc lamps, tungsten lamps, and lasers. The light filter is the process of filtering the light so that the fluorometer can only detect light with specific wavelength. The filters also used to absorb visible radiation. There are usually two types of filter in fluorometer, which are the absorption filter and interference filter.

The detector is the phase where light energy is converted to electrical signal and the data is recorded by the microcontroller. The transmitted radiation falls on the component that act as the detector and the intensity of absorbed radiation is determined. The component that likely to be used as the detector is the photodiode or a photomultiplier.

3.3 SYSTEM OVERVIEW

The instrument consists of several elements that are important to build. Each part plays vital role to make sure the instrument is fully function. Figure 3.2 represent the overview system to build the instrument for this project.

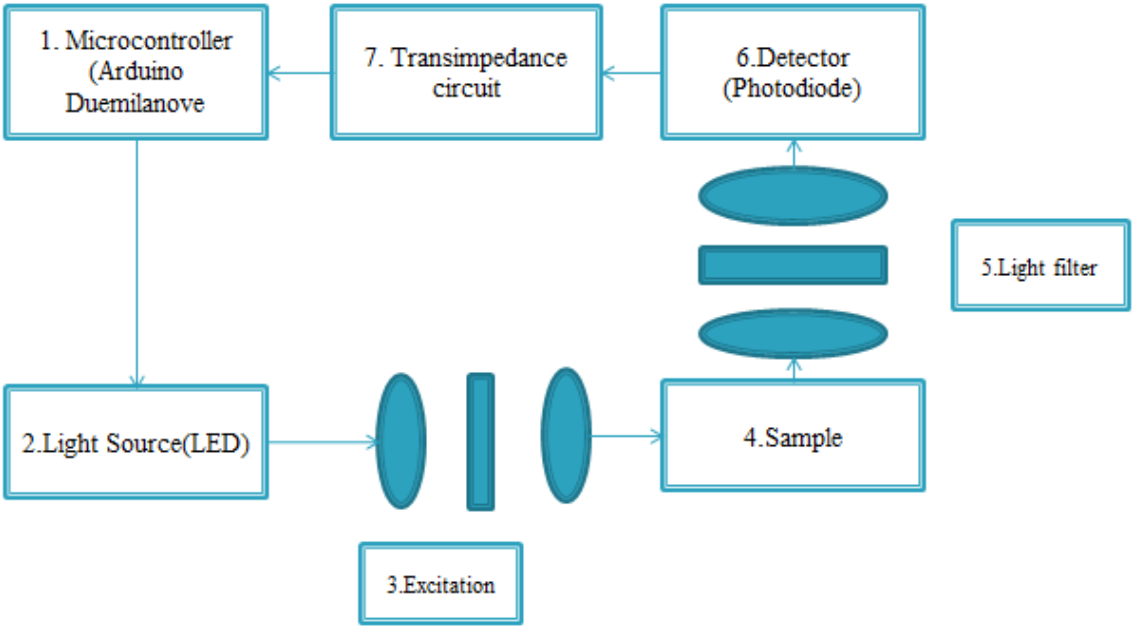

Figure 3.2: The fluorometer overview 1) microcontroller; 2) Light-emitting diode; 3) Excitation phase, containing lens and filter; 4) Sample containing phytoplankton; 5) Light filter, containing lens and filter; 6) Detector, photodiode 7) Transimpedance circuit.

3.3.1 Lens Calculation and Position

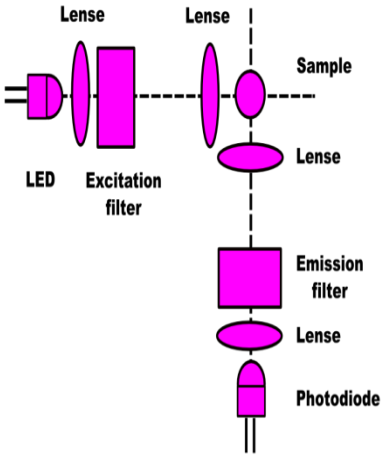

Figure 3.3: Component and lens arrangement for fluorometer

This project will be using double- convex lens for the excitation and light filter process. Focal length, f of a double-convex lens can be determined using the following formula;

$$\frac{1}{f} = \frac{1}{do} + \frac{1}{di} \tag{3.1}$$

f= focal length

d_o= object distance

d_i= image distance

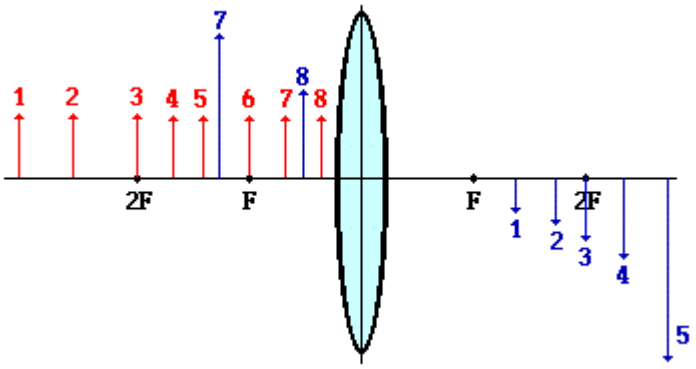

Figure 3.4: The convex lenses object and image position; red line is the object distance; blue line is the image distance.

The magnification of ratio 1:1 occurs at object distance twice the focal length, d_o= 2F.

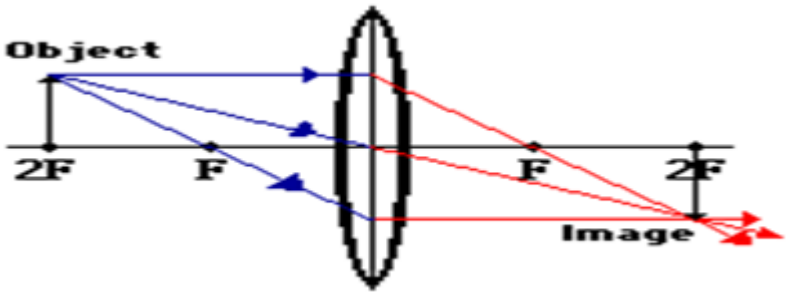

Figure 3.5: Ray diagram for object located at 2F.

The standard sample size for phytoplankton population is $2cm^{3.}$ In this project, the sample that will be used is in cylindrical shape. The diameter of the cylinder is fixed at 10mm length, and from the volume of cylinder formula;

$$V = \pi r^2 h \tag{3.2}$$

V= volume

r= radius

h= height

The height obtained is 2.54cm.The suitable lens diameter use for this project is 10mm.

3.3.2: Microcontroller

Microcontroller is a self-contained peripherals, processor and a memory that can be used as an embedded system. Most consumer products or machinery these day are embedded with a microcontroller including automobiles, home appliances and phones. Microcontroller is also known as embedded controller. It is the heart of an instrument. Some microcontroller are more complicated but some only have minimal requirements for memory and programming length.

Arduino Uno is chosen to be the microcontroller for this project. Uno in Italian means one and the name was chosen to mark the release of Arduino 1.0. Arduino Uno board is based on the ATmega328P. It contains 14 digital input / output pins and six of them can be used as Pulse Width Modulation outputs. It also has six analog inputs, 16MHz quartz crystal, power jack, ICSP header, USB connection and lastly a reset button.

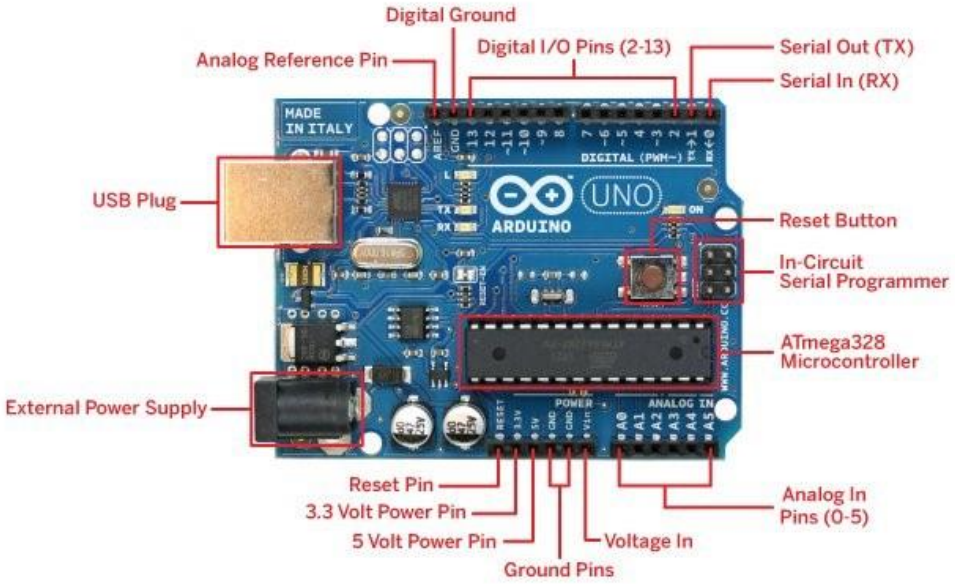

Figure 3.6: The detail on the Arduino Uno board

Table 3.1: Technical specifications of Arduino Uno

Microcontroller	**ATmega328P**
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

3.3.3 Data Logger

A data logger is an electrical instrument that can records required measurements over a period of time. The measurement maybe physical or electrical parameter. Data logger can be used in variety of applications such as environmental monitoring, health monitoring and in-vehicle data logging. The common measurement include voltage, pressure, temperature, force, and acceleration.

This project used Ethernet Shield V2.0 as the data logger. This shield is fully compatible with Arduino Uno and it allows another shield to be stacked on top of it. It also supports micro SD card read/write.

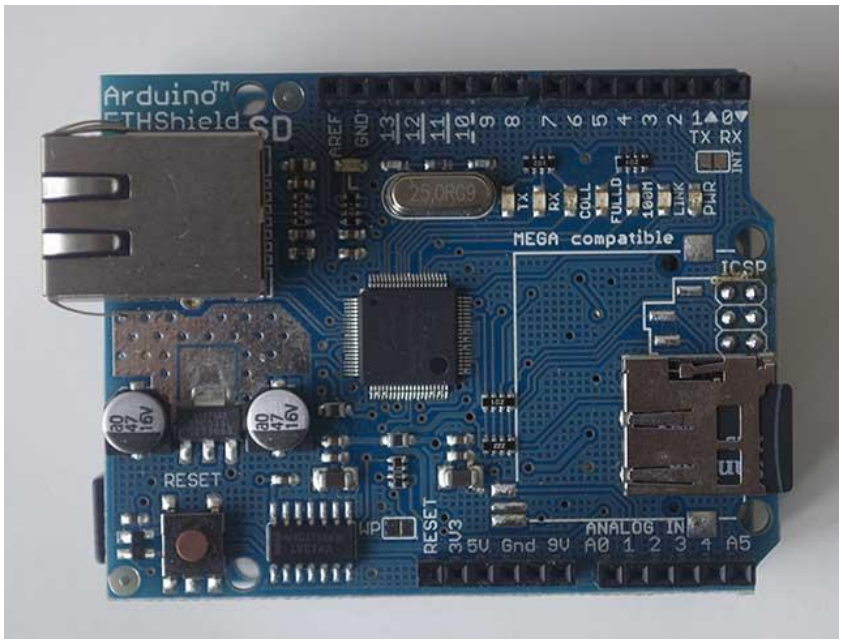

Figure 3.7: Ethernet Shield V2.0

Table 3.2: Pin connection between Ethernet Shield V2.0 and Arduino Uno

Arduino / Genuino Board	MOSI	MISO	SCK	SS (slave)	SS (master)	Level
Uno	11	12	13	10	-	5V

3.3.4 Light Source

Blue LED HLMP-CB15 is chosen to be the light source for this project. It can projects 472nm typical dominant wavelength light. The combination of chlorophyll and the other cellular component within the phytoplankton cell have the absorption up to 440nm. The maximum fluorescence is at 685nm. The LED is reliable as to project the wavelength in within the range of phytoplankton absorption.

Figure 3.8: Blue LED HLMP-CB15

Table 3.3: Blue LED HLMP-CB15 specification

Parameter	Value	Units
DC Forward Current	30	mA
Peak Forward Current	100	mA
Average Forward Current	30	mA
Power Dissipation	120	mW
Reverse Voltage (I_R = 100µa)	5	V
LED Junction Temperature	130	^oC
Operating Temperature Range	-40 to +80	^oC
Storage Temperature Range	-40 to +100	^oC

3.3.5 Detector

The fluorescence measurement and detector for this project is using the Photodiode VTB1113.The component is chosen because the spectral application range is within 320nm and 1100nm. It is within the range phytoplankton absorption and fluorescence.

Figure 3.9: Photodiode VTB1113

Table 3.4: Photodiode VTB1113 specification

Symbol	Characteristic	Test Conditions	Min.	Typ.	Max.	Units
I_{SC}	Short Circuit Current	H=100 Fc, 2850 K	30	60		µa
TC I_{SC}	I_{SC} Temperature Coefficient	2850 K		0.12	0.23	%/°C
V_{OC}	Open Circuit Voltage	H=100 Fc, 2850 K		490		mV
TC V_{OC}	V_{OC} Temperature Coefficient	2850 K		-2.0		mV /°C
I_D	Dark Current	H=0, VR=2.0V			20	Pa
R_{SH}	Shunt Resistance	H=0, V=10mv		7.0		GΩ
TC R_{SH}	R_{SH} Temperature Coefficient	H=0, V=10Mv		-8.0		%/°C
C_J	Junction Capacitance	H=0, V=0		0.31		Nf
S_R	Sensitivity	365nm		0.19		A/W
λRange	Spectral Application Range		320		1100	Nm
λ_P	Spectral Response-Peak			920		Nm
V_{BR}	Breakdown Voltage		2	40		V
$\theta_{½}$	Angular Resp. -50% Resp. Pt.			±15		Degrees
NEP	Noise Equivalent Power			5.9 X 10-15 (Typ.)		W/√Hz
D*	Specific Detectivity			2.1 X 10 13 (Typ.)		Cm √Hz/ W

3.3.6 Transimpedance Circuit

The current produce by the photodiode was amplified using and transimpedance circuit that also act as the current-to-voltage converter.

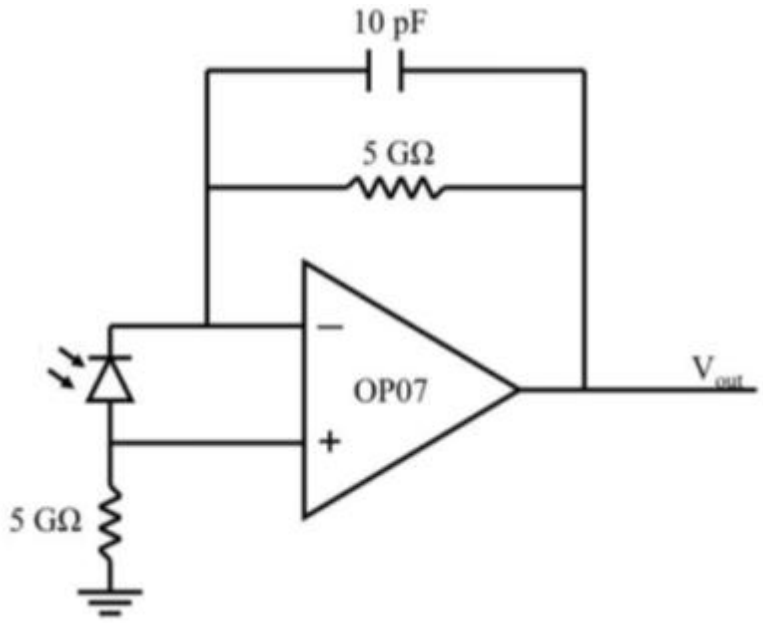

Figure 3.10: Transimpedance circuit

The transimpedance circuit use component like precision operational amplifier OP07 and 5GΩ resistors. The output of the amplifier is connected to one the Arduino analog pins so that the detector will record the output. The Arduino analog pins are capable to measure voltage between the ranges of 0 to 5V with 10-bits resolution. Voltage measured will be stored in the SD card.

3.4 BILL OF MATERIAL

These are the bill of the materials used in making this instrument.

Table 3.5: Bill of material

No.	Component /Part	Quantity
1	Arduino Uno	1
2	Ethernet Shield V2.0	1
3	Photodiode VTB1113	1
4	5GΩ Resistors	2
5	Precision Operational Amplifier (Op07)	1
6	10 pF Capacitor	1
7	Convex Lens (f = 10 mm)	3
8	16 GB SD Card	1
9	Blue LED HLMP-CB15	1

3.5 DATA COLLECTION AND ANALYSIS

The completed instrument will be tested with live phytoplankton specimen. It will also be tested with in situ sample obtained from beach nearby Universiti Malaysia Pahang. The results will be compared to determine the parameter of which the phytoplankton detected. The instrument will be tested with different water sample and the presence and absence of phytoplankton in it. The result will be determined by the different of the measurement when phytoplankton is detected.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter contains the outcomes acquired throughout the project. The breakdown of this chapter will discuss the hardware and circuit diagram used in the project. It also covers the results of experimental and field results. The architecture and characteristics of the components and devices is included in this chapter. This project is to create an instrument that can detect phytoplankton.

4.2 FINAL PROTOTYPE MECHANISM

The instrument was fabricated for the purpose of this study which is to design an instrument for unmanned surface vehicle for phytoplankton detection.

Figure 4.1: View of instrument casing 1

Figure 4.2: View of instrument casing 2

Figure 4.3: View of instrument casing 3

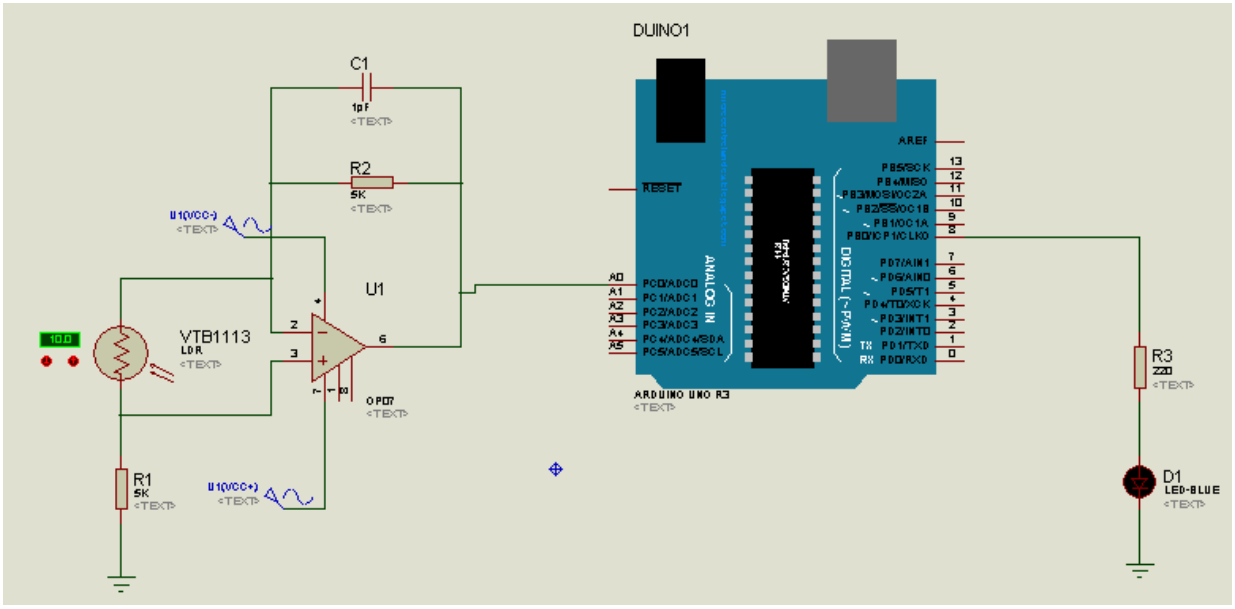

Figure 4.4: The circuit diagram for the instrument

Figure 4.4 present the circuit diagram used for this project. The right side of the figure shows the connection of Blue LED HLMP-CB15 and 220 Ohm resistor with Arduino Uno digital pin 8. The function of this part of the circuit is to light up the LED that acts as the light emitter for the instrument. The left side of the figure shows the connection of transimpedance circuit and the photodiode VTB1113 with Arduino Uno analog pin A0. Current produced by VTB1113 photodiode is amplified and converted into voltage by the transimpedance circuit that consist of OP07 operational amplifier, 10 pF capacitor and two 5G Ohm resistors. The voltage output is then read by the Arduino Uno analog pin and the values are saved in SD card by using Ethernet Shield V2.0. The circuit requires very few components and can be constructed with minimal soldering.

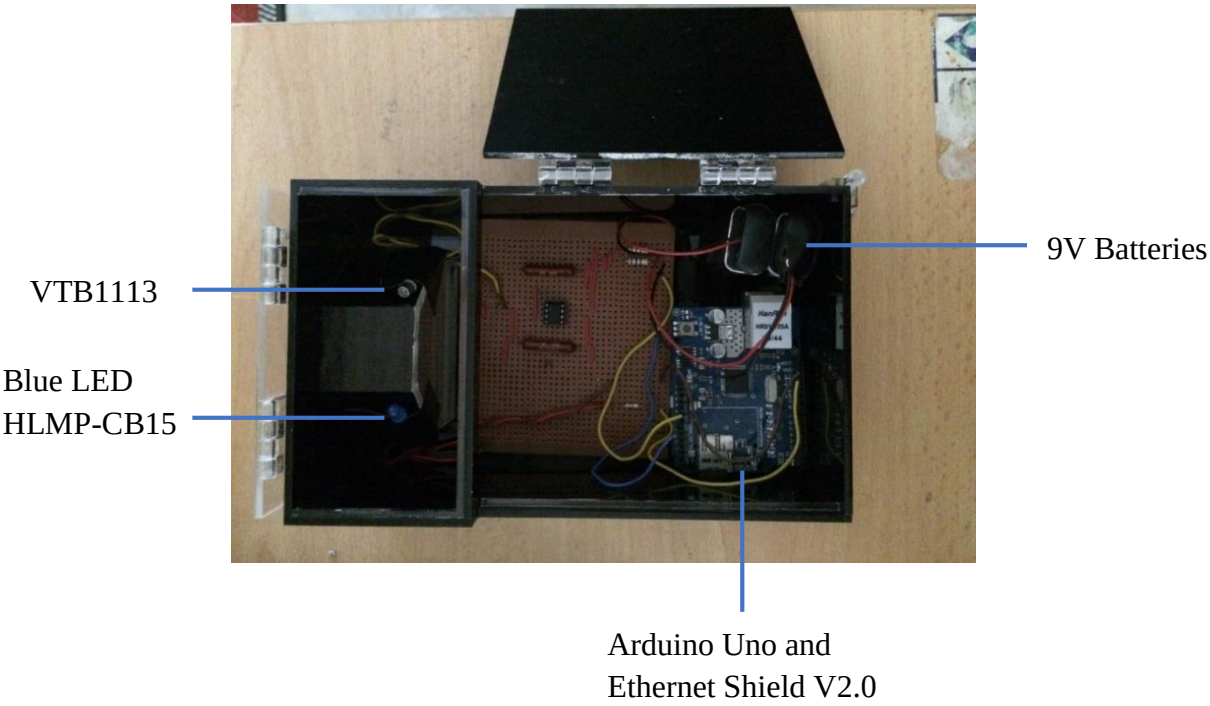

Figure 4.5: Electric circuit implemented into the casing

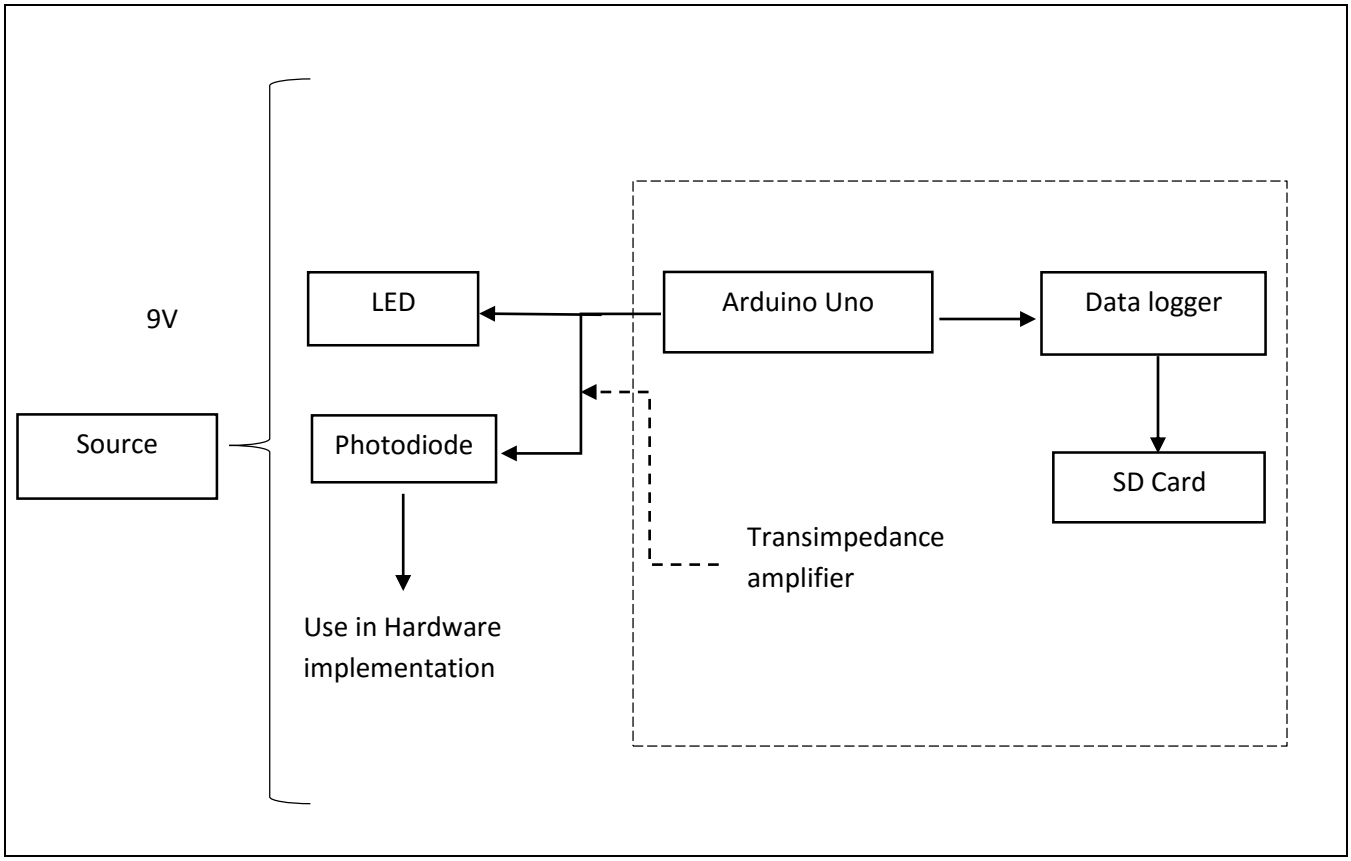

Figure 4.6: Block diagram of the instrument

4.3 LABORATORY TEST

The instrument is tested with live phytoplankton sample to prove its functionality. It will be tested with 4 types of water samples which are seawater with dinoflagellates, seawater without dinoflagellates, freshwater with mix species algae and freshwater without algae. All of water samples is obtain from collaboration with Universiti Islam Antarabangsa, Gombak. For each sample, 3 measurements will be taken. Each type of water will be divided in to 3 small samples to obtain more reliable reading. The sensor can take more accurate reading as the volume of sample tested getting smaller. The area covered by the sensor is small thus with smaller volume sample, the reading will be more accurate and precise. Figure 4.6 presents the water samples tested for this project.

Figure 4.6: Water sample 1) Seawater with dinoflagellates 2) Seawater without dinoflagellates 3) Freshwater with mix species algae 4) Freshwater without algae

The water samples is divided into 3 small tubes to be tested by the instrument. For each sample the reading is taken every 5 seconds and over 500 readings taken from each sample. The time taken for whole 500 reading is 2500 seconds which is equal to 41 minutes and 40 seconds. The instrument is built so that it can be embedded into an unmanned surface vehicle, thus the measuring time is made longer to suit the purpose. For other measurement time, the Arduino coding must be altered according to the user need. Figure 5.2 present the sampling tubes used in this project.

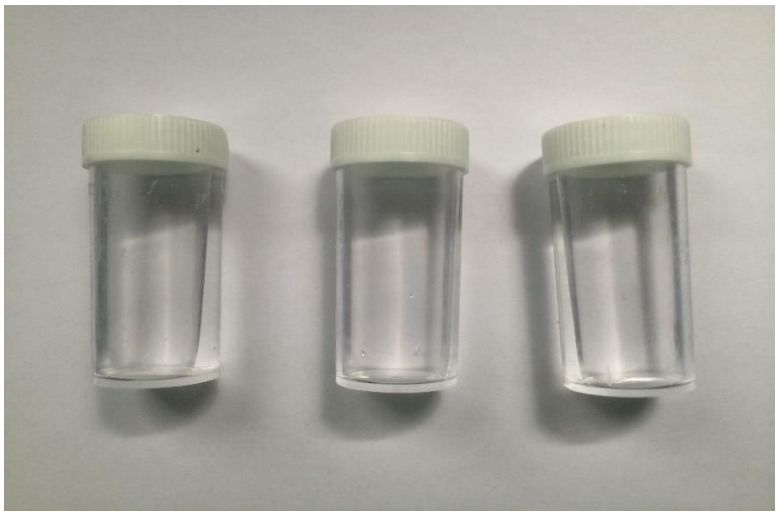

Figure 4.7: Sampling tubes

The test is done by putting the tube on top of the sensor area of the instrument. The instrument is turned on and the sample is let rest on it for the required period on time. The best condition to test the sample is in dark condition. When the testing is finished, the data is collected from the SD card and graph of bits against time of measurement is plotted for each sample. Figure 4.8 presents the position of sample on top of the instrument while the testing is taken place.

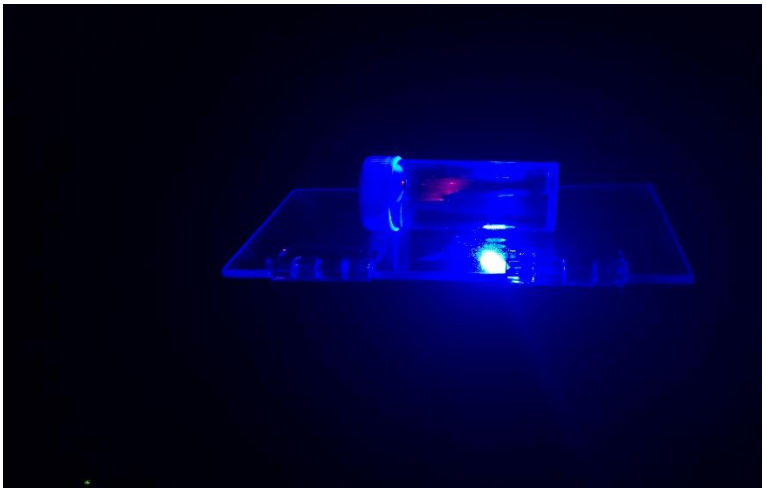

Figure 4.8: Sample position on instrument

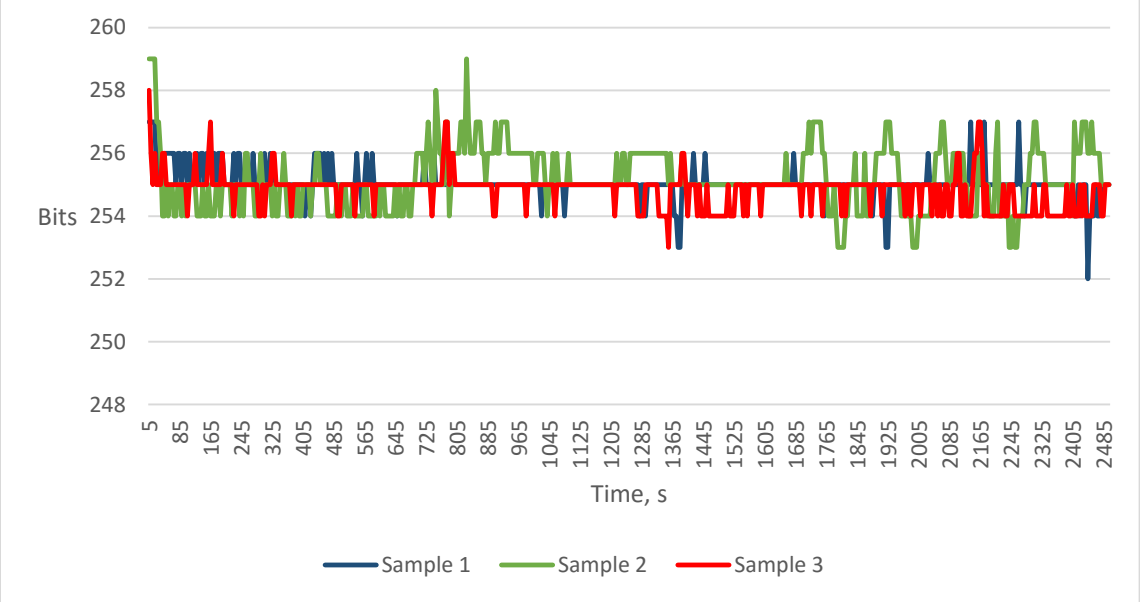

Figure 4.9: Graph of bits against time of freshwater with phytoplankton

Sample 1 for freshwater with phytoplankton recorded the highest bits reading at 259 bit and the lowest reading at 253 bit. Sample 2 recorded reading between 258 bit and 252 bits. Sample 3 recorded the highest bit reading at 258 bits and the lowest at 253 bits. Overall freshwater with phytoplankton recorded bits reading ranged from 259 bits to 252 bits for reading time of 2500 seconds.

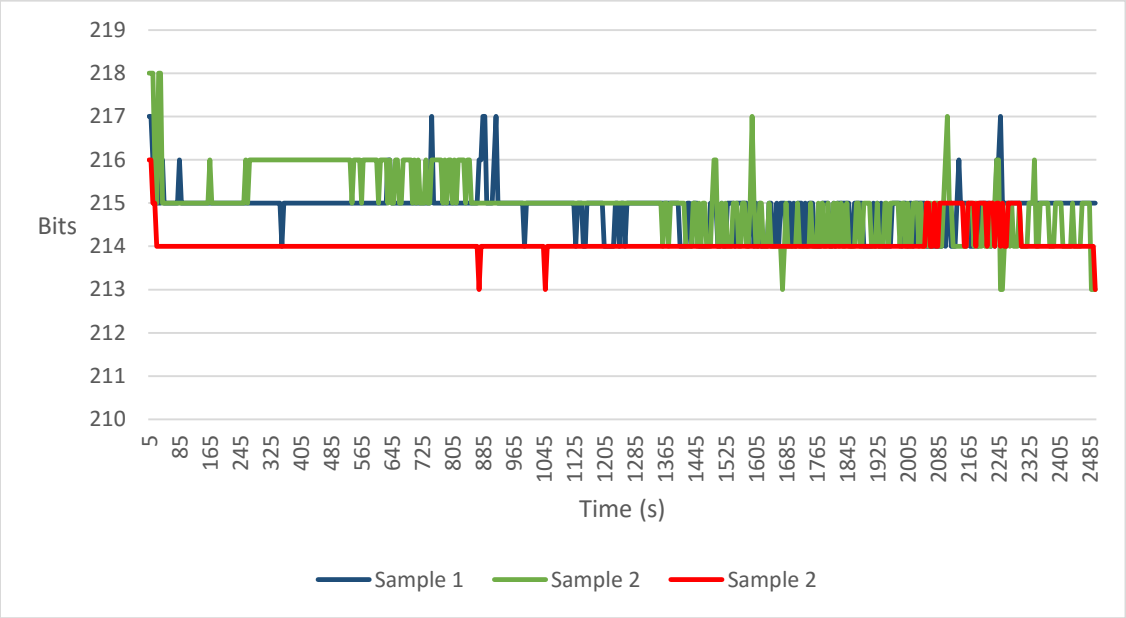

Figure 4.10: Graph of bits against time of freshwater without phytoplankton

Sample 1 for freshwater without phytoplankton shows the reading between 217 bits to 214 bits. Sample 2 recorded the highest reading of 218 bits and lowest reading of 213 bits and lastly sample 3 shows reading between 216 bits to 213 bits. Freshwater without phytoplankton shows bits reading ranged between 218 bits to 213 bits.

The overall trend for freshwater is that the freshwater with phytoplankton recorded higher bits reading compared to freshwater without phytoplankton. The trend is clearly shown in comparison between Figure 4.9 and Figure 4.10. Freshwater with phytoplankton for this project is freshwater with mix species algae and from the Figure 4.9. It is shown that the water sample contains more fluorescence properties compared to freshwater without phytoplankton.

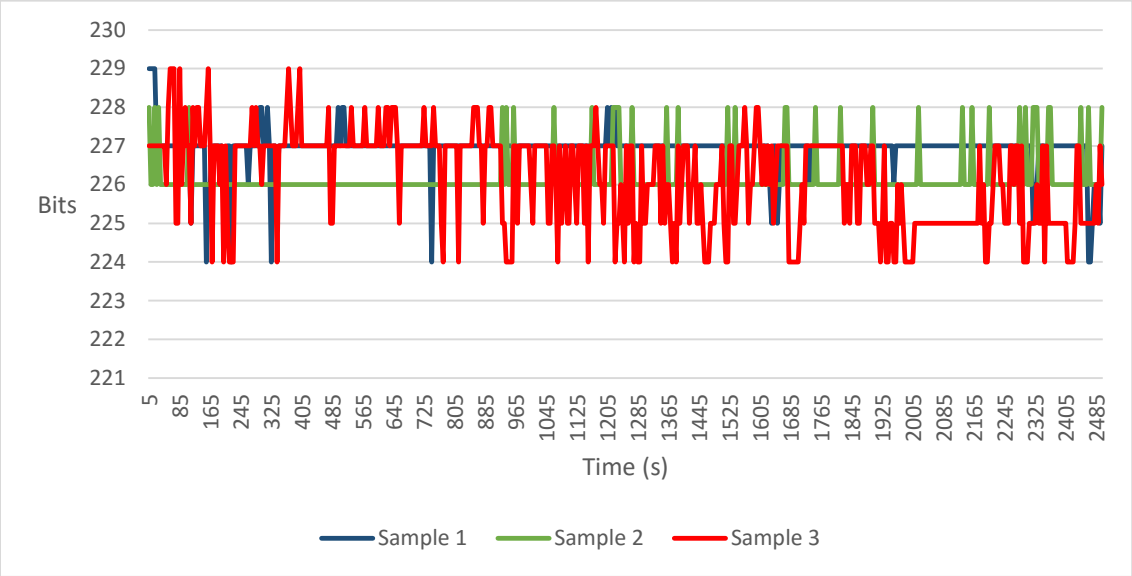

Figure 4.11: Graph of bits against time of seawater with phytoplankton

For seawater with phytoplankton, sample 1 recorded bits reading between 229 bits to 224 bits. Sample 2 recorded highest bits reading of 228 bit and lowest reading of 226 bits meanwhile sample 3 shows reading from 229 bit to 224 bits. Overall, seawater with phytoplankton recorded bit reading ranged between 229 bits to 224 bits.

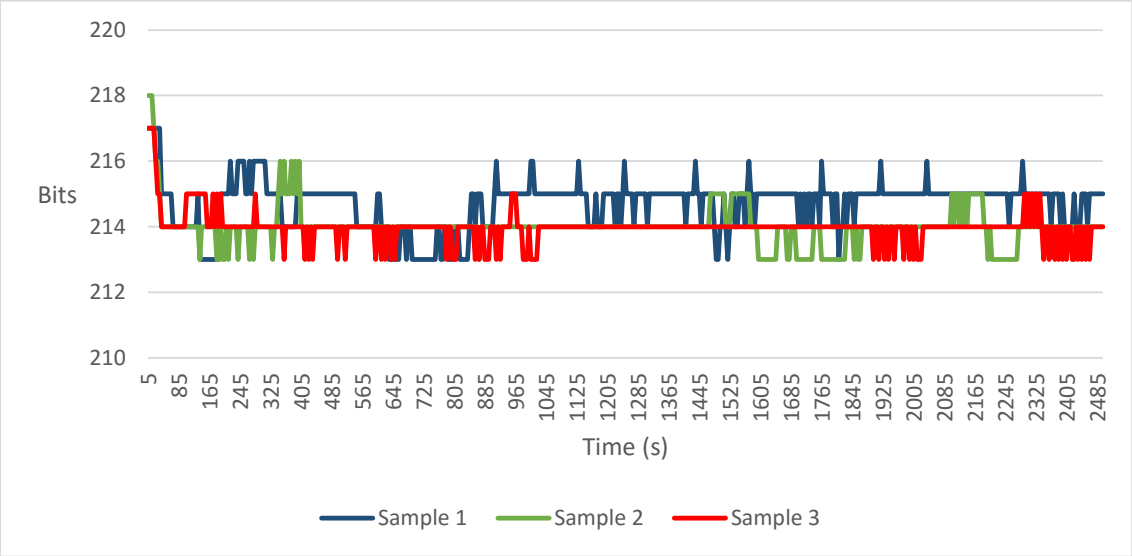

Figure 4.12: Graph of bits against time of seawater without phytoplankton

Seawater without phytoplankton for sample 1 and sample 3 both recorded highest bits reading of 217 bits and lowest bit reading of 213 bits. Sample 2 shows bits reading between 218 bits to 213 bits.

The overall trend for seawater is like freshwater where seawater with phytoplankton recorded higher bit reading compared to seawater without phytoplankton. Figure 5.5 shows that seawater with phytoplankton has the higher bits reading compared to seawater without phytoplankton. The fluorescence properties contain in seawater with phytoplankton is higher as it contains phytoplankton of dinoflagellate species in it. The presence of phytoplankton of dinoflagellate species in one of the seawater sample makes the reading relatively higher than the others.

4.4 IN SITU SAMPLE TEST

The instrument is empowered with two 9V batteries to allow it to warm up the blue LED and collect the sample data. The LED is let to warm up to achieve it stable output. After the LED is stable, the measurements are taken and the LED is allowed to run continuously. Then the data collected will be stored in SD card through the data logger. The data in the SD card can be corrupted if the voltage drop below 6V. Thus the batteries used must be in full power and great condition.

A sample is collected at beach nearby, Lagenda Beach, Pekan Pahang. The sample is tested using the same method.

Figure 4.13: Seawater sample collected at Lagenda Beach.

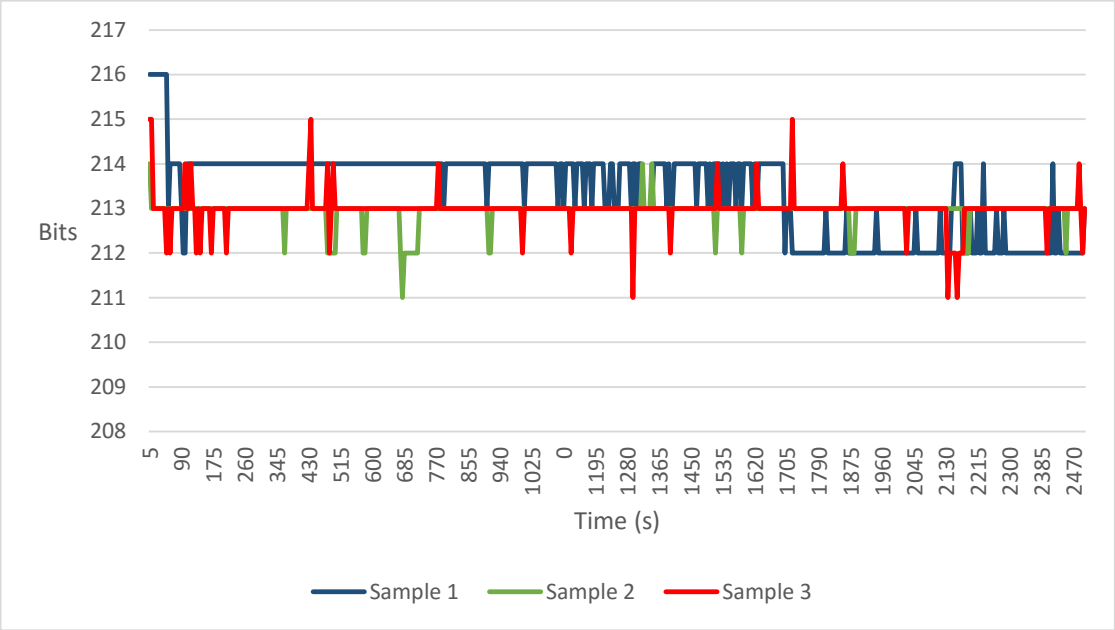

Figure 4.14: Graph of bits against time of sample from Lagenda Beach.

The seawater collected from Lagenda Beach is tested. Sample 1 recorded the highest reading of 216 bits and the lowest reading of 212 bits. Sample 2 recorded reading between 215 bits to 212 bits and sample 3 reading is from 214 bits to 211 bits. Overall, the sample from Lagenda Beach recorded bits reading ranged from 216 bits to 211 bits.

For each water sample, the bits reading is not consistent at only one value as the water contain live phytoplankton species. The reading may be influenced by the presence of sand and dust in the water or outside the sampling tube and also by the movement of phytoplankton. The tests were carried out in dark room with room temperature. Dark condition is important to avoid ambient light from affecting the measurement. The tests are done at night to minimize the influence of ambient light towards the reading.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter summarizes the whole project by coming up with conclusions from the result produce from this project. This chapter also covers the conclusion and recommendations that can be implemented to improve this project in the future.

5.2 CONCLUSION

The aim of this research was to design an instrument that can be used to detect phytoplankton in situ. In order to achieve the objectives, a study needs to be done to know the detectability of phytoplankton. The study is to know how to detect phytoplankton in the suitable way for an instrument such criteria to be build. From the study, the best way to detect phytoplankton is to detect the fluorescent properties of chlorophyll a, which contained inside phytoplankton cells. With the chlorophyll a have maximum absorption centred 440nm and maximum fluorescence at 685nm, suitable components are selected to build up an instrument. The casing of the instrument is made in a suitable size to put the sample on while the testing is taking place and to be embedded into the unmanned surface vehicle. Some of the casing surface is built totally opaque to avoid light strained and affecting the result. The Arduino analog pins are measuring the voltage from 0 to 5 V and

resolution of 10-bits resolution. The count is ranging from 0 to 1023 bits. To obtain the voltage value of the reading some calculation have to be made using this formula.

$$Voltage = \frac{5V}{1023}\ x\ Bit\ reading \tag{5.1}$$

In general the precision of this instrument is at 0.005 Volt per bits count.

Based on the experiment that was conducted, the overall trend is when the sample water contains phytoplankton, it will record higher bits reading from the sample water without phytoplankton. The presence of phytoplankton in the water sample causing the instrument to record higher bit reading .The phytoplankton contains unique fluorescent properties from chlorophyll *a* that making the reading slightly higher. Freshwater with phytoplankton has bits reading over time ranged from 259 bit to 252 bits compared to freshwater without phytoplankton that only recorded only 218 bit to 213 bits reading. Seawater with phytoplankton recorded readings between 229 bit to 224 bits and seawater without phytoplankton only recorded reading of 218 to 213 bits. In situ sample from Lagenda Beach recorded reading from 216 to 211 bits. The reading trend is lower compared to seawater with phytoplankton and almost similar to seawater without phytoplankton result. With the comparison, the seawater taken from Lagenda Beach may not contains any phytoplankton.

The functionality of this instrument is to detect the fluorescence of chlorophyll *a* in the phytoplankton. During both laboratory and situ tests, the instrument demonstrated excellent response to chlorophyll a florescence. The construction of this instrument is simple, inexpensive and battery operated suitable for the determination of in situ phytoplankton presence.

5.3 RECOMMENDATIONS

There are many improvement that can be made. Proper improvement is needed to make sure the instrument can be more accurate and versatile. This instrument is very sensitive to ambient light. The sensor cannot differentiate the ambient light and light reflected from the phytoplankton. It would be very difficult and unreliable to use the instrument in daylight. The sensor can easily be saturated by the ambient light and for daylight operations this need to be overcome.

One of the solutions is to develop the instrument with a flow through system. The measurement will be taken inside a tube to avoid the presence of ambient light. The tube must in opaque rigid state to avoid ambient light passed through it. This is the improvement that can be apply to make the instrument useful in daylight operations and to avoid ambient light from disturbing the result required from the measurement. This improvement is pretty reliable and easily executed. The cost to perform this improvement is cheap and affordable.

The other way to avoid ambient light from influencing the result is to modulate the light source and using a high frequency filter for the detection. The light source modulation will resulting the light form fluorescence to reach in high frequency pulses. The high frequency filter will block low frequency signals and allow only high frequency signal to get through. The modulation process can be achieved by using the built in digital pins of Arduino. The digital pins can be used for pulse width modulation (PWM). The pins can drive the light emitter at high frequencies. At any frequency required the digital pins can be switched from 0 to 5 V and this allows for frequency and duty cycle of light emitter to be customized at any value required. This ambient light rejection method is widely used in many optical devices but this will also increases the complexity to make the instrument.

The performance of this instrument can be increased by comparing the reading obtains from the instrument to a commercial manufactured fluorometer. However, the price of commercial manufactured in situ fluorometer is high. Extra funding is needed to rent or buy commercial manufactured fluorometer. One of the commercial manufactured fluorometer that can be used is WetLabs WETStar fluorometer. The retail price for the fluorometer is more than US $3000 (Thomas Leeuw et al. 2013). The process of comparison of data with Medium Resolution Imaging Spectrometer (MERIS) and Moderate Resolution Imaging Spectroradiometer (MODIS) is more complicated and unavailable to some individuals.

REFERENCES

This thesis is prepared based on the following references;

A.Anton, P.L. Teoh, S.R. Mohd-Shaleh, N. Mohammad-Noor (2008).First occurrence of Cochlodinium blooms in Sabah, Malaysia

A.S.M. Saifullah, M.K. Abu Hena, M.H. Idris, A.R. Halimah and I. Johan, 2014. Composition and Diversity of Phytoplankton from Mangrove Estuaries in Sarawak, Malaysia. Journal of Biological Sciences, 14: 361-369.

Angus J Fraser, John R Sargent (1998). Formation and transfer of fatty acids in an enclosed marine food chain comprising phytoplankton, zooplankton and herring (Clupea harengus L.) larvae

Babin, M. Phytoplankton Fluorescence: Theory, Current Literature and in-situ Measurement. In Real-Time Coastal Observing System for Marine Ecosystem Dynamics and Harmful Algal Blooms; Marcel, B., Collin, S.R., John, J.C., Eds.; United Nations Educational, Scientific and Cultural Organization: Paris, France, 2008; pp. 237–280.

C.B. Field, M.J. Behrenfeld, J.T. Randerson, P. Falkowski(1998). Primary production of the biosphere: integrating terrestrial and oceanic components

Corrales RA, Gomez ED (1990) Red tide outbreaks and their management in the Philippines. In:

Douma, M., (2008). Cause of Color. Retrieved January 25, 2016, available from http://www.webexhibits.org/causesofcolor.

Geoffrey G Schofield (2004). PicoGmeter, a custom-made fluorometer for the quantification of dsDNA by PicoGreen fluorescence.

Graneli E et al. (eds) Toxic marine phytoplankton, pp. 453-458. Elsevier Publishing Co, New York

Hannah M. Murphya, Terry Bungayb, Edward W.P. Sterna, Paul D. Wingerb, Dominique Roberta (2015). Measurement of warp loads of bongo plankton samplers

Junlei Lia, Xiaoxia Suna, Shan Sheng (2013). In situ study on photosynthetic characteristics of phytoplankton in the Yellow Sea and East China Sea in summer 2013

Lin II, Soo CL, Hock L, Leong KK, Michael H, Serena T, Siong TK, Karina G (1999) Classification of tropical algal bloom types by sea truth spectral radiometric data.

Lorenzen, C.J. A method for the continuous measurement of *in vivo* chlorophyll concentration. *Deep Sea Res.* 1966, *13*, 223–227.

Pengfei Zhanga, Le Liuc, Yi Taod, Qiang Huanga, Heng Shia, Chan Dua, Xihui Zhangd, Yonghong Hea, (2013). An amplitude modulation fluorometric method for phytoplankton classified measure

Richardson K (1997) Harmful or exceptional phytoplankton blooms in the marine ecosystem. Adv.Marine Biology 31, 301-385.

Schirber, M. (2013). The Full Palette of Photosynthesis. Retrieved February 25, 2016. Available from http://www.astrobio.net/news-exclusive/the-full-palette-of-photosynthesis/

Thomas, J.B.; Flight, W.F.G. Fluorescence responses of chlorophyl*l in vivo* to treatment with acetone. *Biochim. Et Biophys. Acta* 1964, *79*, 500–510.

Thomas Leeuw, Emmanuel S. Boss and Dana L. Wright (2013). In situ Measurements of Phytoplankton Fluorescence Using Low Cost Electronics

Universiti Malaysia Sabah (2005) Red tide. Retrieved January 14, 2016. Available from: http://www.ums.edu.my.

Yongmin Kim, Younggi Byun, Yongil Kim, Yangdam Eo (2009).Detection of Cochlodinium polykrikoides red tide based on two-stage filtering using MODIS data

Zhixin Ke, Yehui Tan, Liangmin Huang (2011). Spatial variation of phytoplankton community from Malacca Strait to southern South China Sea in May of 2011

APPENDIX

A: ARDUINO CODING

```
//DESIGN AND ANALYSIS OF UNMMANED SURFACE VEHICLE INSTRUMENT FOR PHYTOPLANKTON DETEECTION

//MUHAMMAD HISYAM BIN AZMAN

//FB11046



#include <SPI.h>

#include "SD.h"

#include "Time.h"

int read1;

int read2;

int read3;

int read4;

int read5;

int val;

int PHT = 0;

File myFile;

void setup() {

pinMode(4, OUTPUT); //TURN ON DATA LOGGER


if (!SD.begin(4)) {

return;

}

pinMode(PHT, INPUT);
```

```
pinMode(8,OUTPUT); // LED PIN

digitalWrite(8,LOW);

analogReference(DEFAULT); // ANALOG INPUTS BETWEEN 0 AND 5 VOLTS

myFile = SD.open("data.txt", FILE_WRITE); // SPECIFY NAME OF TEXT FILE ON SD CARD

myFile.println("Start"); // PRINTS INITIALIZER 'START'

}

void loop() {

if (myFile) {

for (int j = 0; j < 50; j++) {

delay(5000); // DELAY UNTIL NEXT MEASUREMENT

digitalWrite(8,HIGH);

delay(900); // allow LED to warm up

for (int x = 0; x < 10; x++) { //

read1 = analogRead(PHT);

delay(100);

read2 = analogRead(PHT);

delay(100);

read3 = analogRead(PHT);

delay(100);

read4 = analogRead(PHT);

delay(100);

read5 = analogRead(PHT);

val = (read1+read2+read3+read4+read5)/5; //

time_t t = now(); //

if(month(t) < 10) {

myFile.print(PHT);
```

```
}
myFile.print(month(t));
myFile.print("/");
if(day(t) < 10) {
myFile.print(PHT);
}
myFile.print(day(t));
myFile.print("/");
myFile.print(year(t));
myFile.print(" ");
if(hour(t) < 10) {
myFile.print(PHT);
}
myFile.print(hour(t));
myFile.print(":");
if(minute(t) < 10) {
myFile.print(PHT);
}
myFile.print(minute(t));
myFile.print(":");
if(second(t) < 10) {
myFile.print(PHT);
}
myFile.print(second(t));
myFile.print(" @ ");
myFile.println(val);
}
```

```
digitalWrite(8,LOW); // TURN LED OFF
}
}
myFile.close(); // CLOSES FILE
while(1) { //
digitalWrite(4,HIGH);
delay(1000);
digitalWrite(4,LOW);
delay(2000);
}
}
```

B: GANTT CHART FYP 1

Final Year Project 1

PROJECT ACTIVITY		W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14
Briefing the title by supervisor	P														
	A														
Find and read the journal based on the title of project	P														
	A														
Discuss the suitable journal and book with supervisor	P														
	A														
Do chapter 1	P														
	A														
Discuss and make correction for chapter 1	P														
	A														
Do chapter 2	P														
	A														
Design of product	P														
	A														
Discuss and make correction chapter 2	P														
	A														
Do chapter 3	P														
	A														
Discuss and make correction chapter 3	P														
	A														
Presentation	P														
	A														

C: GANTT CHART FYP 2

Final Year Project 2

PROJECT ACTIVITY		W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W14
Order electronic and mechanical part	P														
	A														
Prepare the material	P														
	A														
Electronic part	P														
	A														
Learn the software	P														
	A														
Mechanical part	P														
	A														
Setup the sensor	P														
	A														
Get the data	P														
	A														
Data analysis	P														
	A														
Do chapter 4	P														
	A														
Discuss and make correction chapter 4	P														
	A														
Do chapter 5	P														
	A														
Discuss and make correction chapter 5	P														
	A														
Final report	P														
	A														
Presentation	P														
	A														