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Mechanical Engineering Department

Graduation Project

Controlling Underwater Camera

Project Team

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Hebron- Palestine

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This project is presented to the Department of Mechanical Engineering at Collage of Engineering and Technology, for partial fulfillment of the graduate project.

Palestine polytechnic university

Hebron Palestine

Collage of engineering and technology

Department of Mechanical Engineering

Controlling Underwater camera (CUC)

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According to the directions of the project supervisor and by the agreement of all examination committee members this project is presented to the department of Department of Mechanical Engineering at college of engineering and technology, for partial fulfillment bachelor of engineering degree requirements.

Supervisor signature

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Committee member signature

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Department Head Signature

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Dedication

First of all thanks and praise to god, for patronizing us to work on this project.

This project is dedicated to our wonderful parents, who have raised us to be the persons we are today. You have been with us every step of the way, through good times and bad. Thank you for all the unconditional love, guidance, and support that you have always given us, helping us to succeed and instilling in us the confidence that we are capable of doing anything we put our mind to. Thank you for everything.

Thanks for our families for their continued support, encouragement and patience from the first step until the end, and their best wishes to us.

To our teachers for their advices and to our friends.

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Abstract

Controlling **U**nderwater **C**amera (CUC) is an applied research to design, analysis, and construct and mechatronics system. User can discover the conditions of place by rotating the camera with desirable degree he want by use the pushbuttons and LCD, to display the desirable degree and the measured degree that will be implemented by rotation of simple DC motor and gears, and use case to isolate the camera, actuator, and other components like the light that will be used in the dark places.

The project presents a challenge in both research and implementation.

مُلخصّ المشروع

CUC هو عبارة عن مشروع بحثي تطبيقي لتصميم وتحليل وبناء كاميرا تحت الماء حيث يتم عزل هذه الكاميرا عن طريق صندوق يعمل على عزلها عن الماء والظروف البيئية الاخرى، يتم التحكم بدوران هذه الكاميرا عن طريق محرك كهربائي ذو جهد مستمر بحيث يمكن للمستخدم تحديد درجة الدوران المطلوبة عن طريق ازرار ضاغطة ويتم عرض هذه الدرجة والدرجة المقاسة على شاشة صغيرة "LCD".

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Introduction

1.1 Introduction

The first attempts in the field of underwater photography were made with a pole mounted camera in the 1850s by the British William Thompson, and several successful attempts were made over the next decades. The first published scientific results from an underwater camera are from 1890 and were made by the French naturalist Louis Boutan (1893) who developed underwater photography to a useful method, inventing the underwater flash and other equipment.

Underwater video has existed since the 1940s. The first published results are by Harvey Barnes in Nature (1952), but it is mentioned in the article that the Admiralty (UK) made successful attempts before that, and that Barnes himself started development of the method in 1948. [1]

Figure 1.1 Louis Boutan, The First Published Underwater Photographer Pioneered Not Only Photography, But Diving Equipment In General

1.2 Recognition Of Need

The need is discovering the sea life, marine studies and researches, and all concerned sectors with the study underwater. Water holes need maintenance to keep clean water for different uses of human beings like: drinking, Irrigate crops, washing clothes, so as known these holes sometimes are deep, have narrow entrance and the going down in is not easy, and may constitute a risk on the human beings from the pressure that is on the body especially in the case of lack of suitable diving suit and under high deep, so these needs must be solved by machine or idea to avoid any risks may face the human in these situations.

1.3 Concept Of The Project

Underwater video systems refers to the equipment used to capture video in water (or other liquids), and to playback the material. The equipment can be divided in components such as camera, housing, carrier (the means of moving the camera around), transmission and/or recording, and finally equipment for viewing. A basic underwater video system consists of a camera in a watertight housing that (optionally) is being moved around on a carrier, and a way to transmit and/or record the pictures to the viewer where they are reproduced.

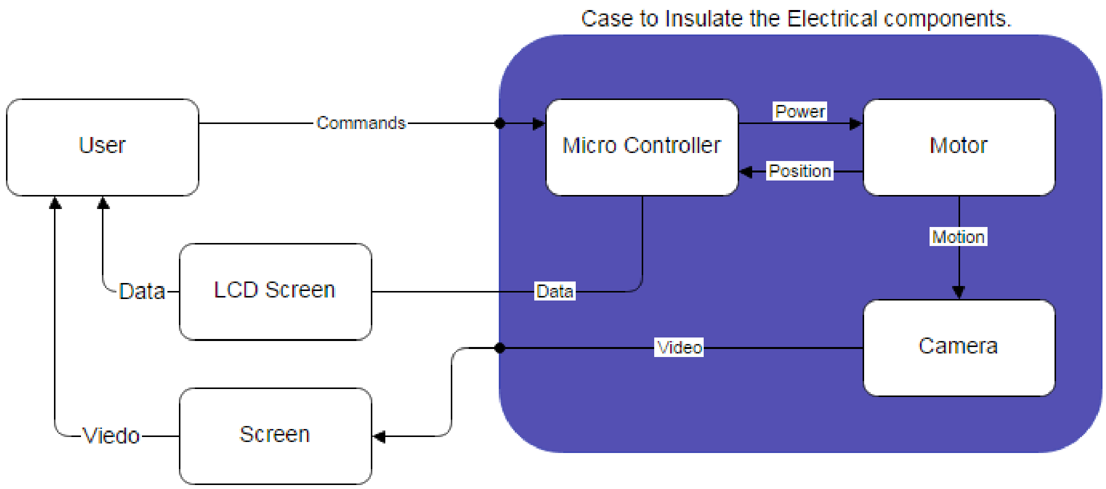

Figure 1.2 Concept of The Project

1.4 Functional Specification

- Depth 40 meter underwater
- Rotation 360^o form -180^o to 180^o.
- Maximum diameter is 6 inch (15.24 cm) depending on the water drilling machine diameter.
- Real-time video viewing.
- Measured angle, desired angle, and temperature measuring and viewing.
- Easy Controlling by users.

Chapter Two

Mechanical Design and Calculations

2.1 Introduction

Design is an iterative process with many interactive phases. Many resources exist to support the designer, including many sources of information and an abundance of computational design tool select.

2.2 Mechanical Design

Before building any device, a set of factors must be considered are: transparency, thickness, type of material, design, dead points, toughness, portability, cost, and design simplicity.

2.2.1 Prototyping

A prototype is an early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. It is a term used in a variety of contexts, including semantics, design, electronics, and software programming. A prototype is designed to test and trial a new design to enhance precision by system analysts and users. Prototyping serves to provide specifications for a real, working system rather than a theoretical one.

From prototyping CUC many things discovered like the buoyancy force, insulation, transparency, lighting effect, and pressure effect on material case.

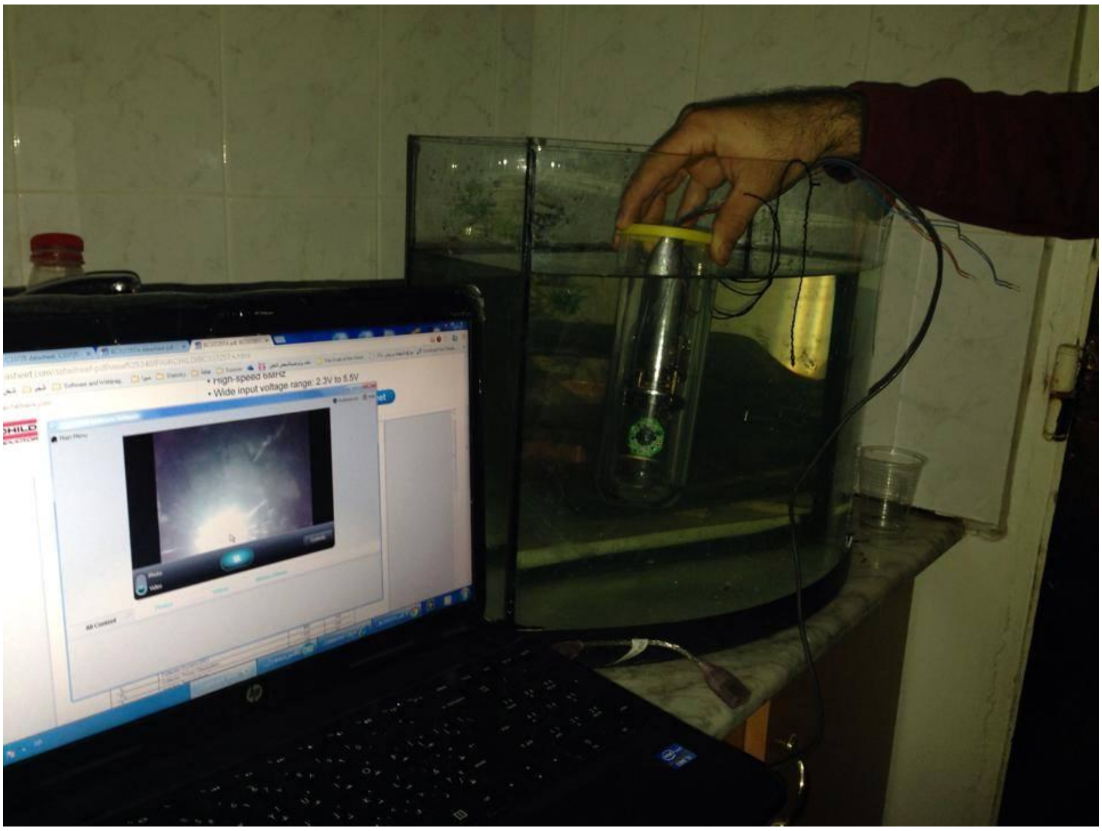

Figure 2.1 Prototype Underwater And Its View On The Laptop.

2.2.2 Mechanical Case

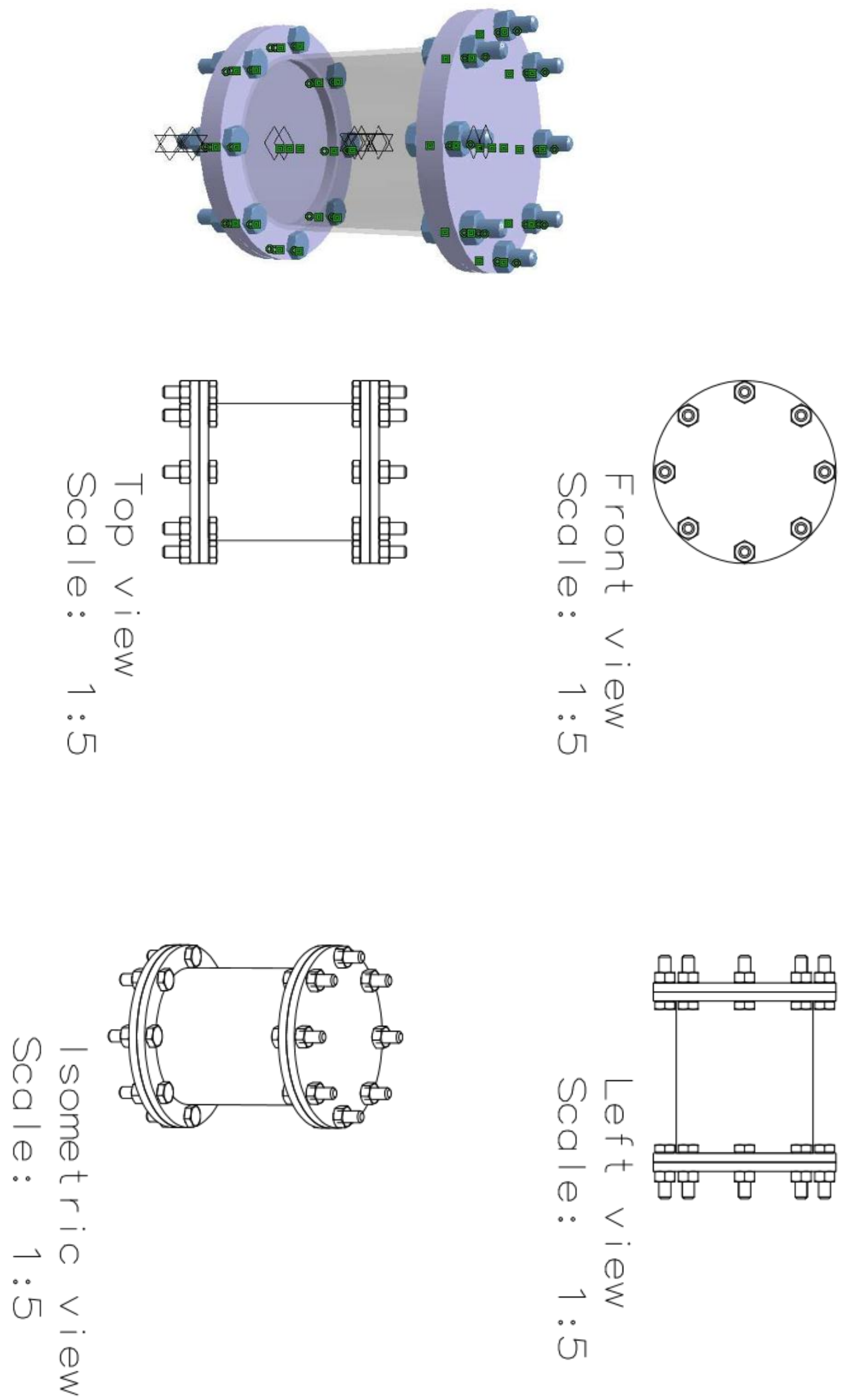

Figure 2.2 First Design For Case.

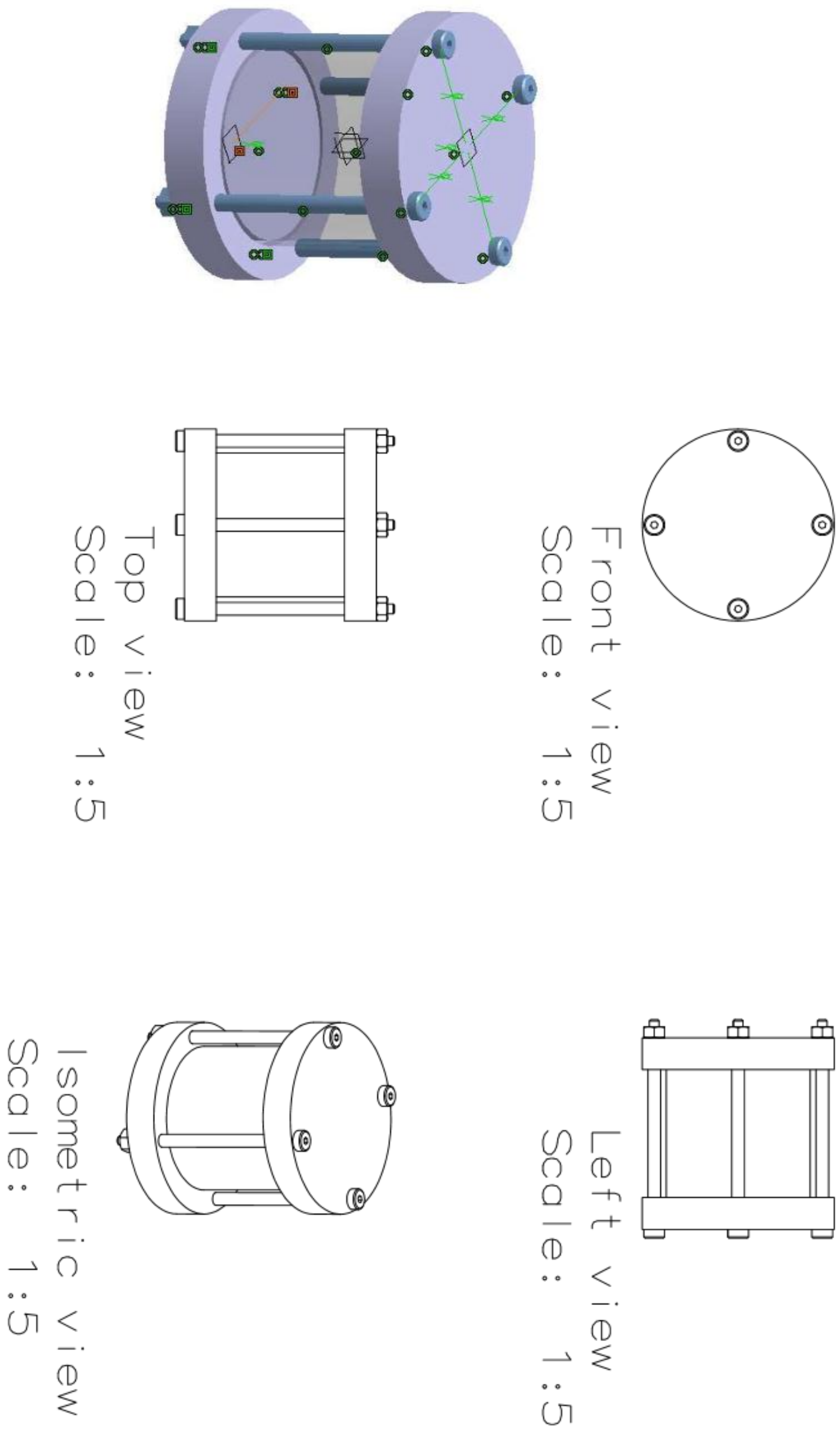

Figure 2.3 Second Design For Case.

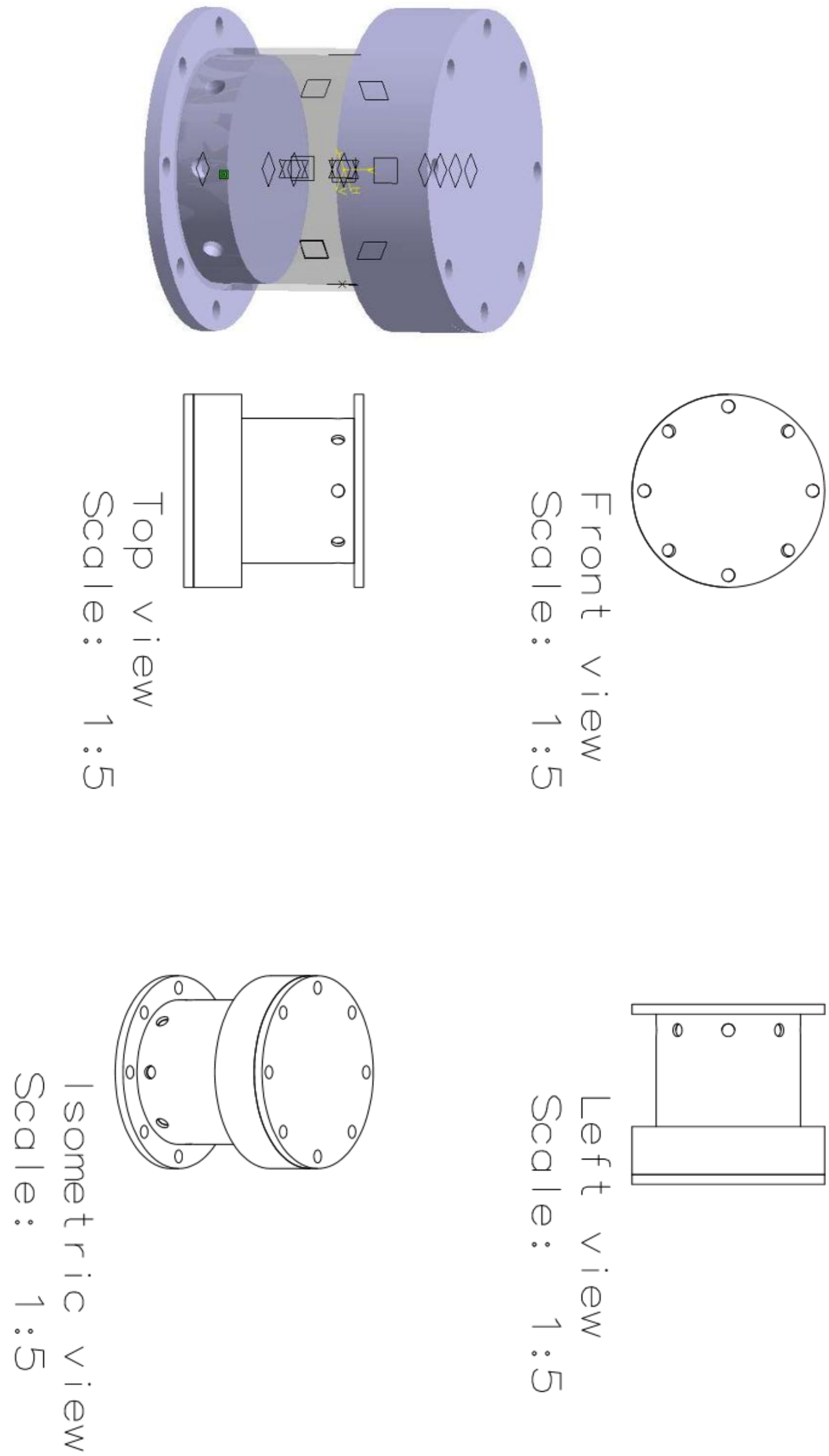

Figure 2.4 Third Design For Case.

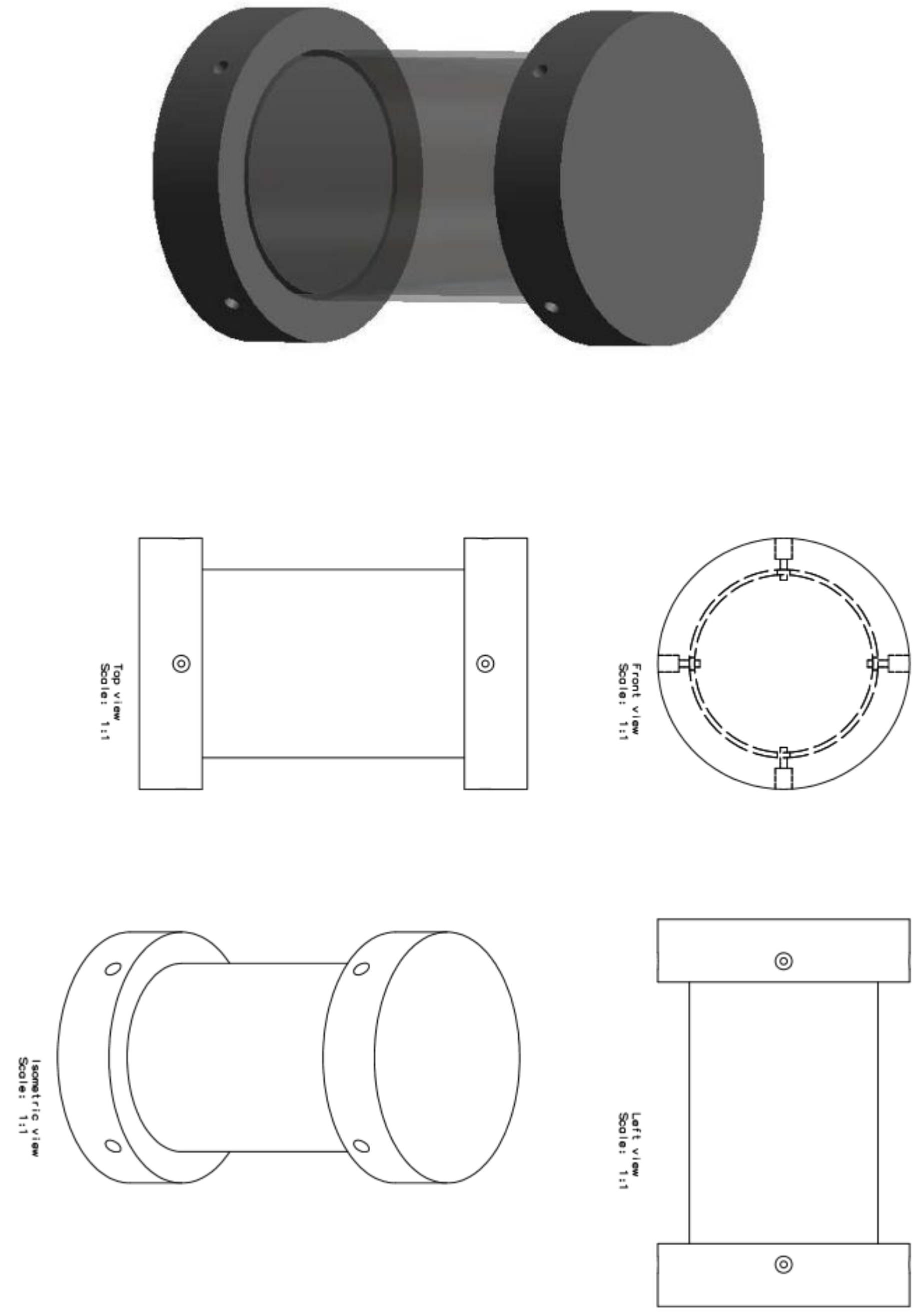

Figure 2.5 Fourth Design For Case.

The first, second, and third designs do not achieve the functional specification, but the fourth achieves the functional specification.

For the first design the disadvantage of this design is: this design is depending on the coupling of the parts with each other, so the main component is the transparent material, and usually this material is brittle, and it's known that the brittle material can be compressed, but can't be tensioned, because of the yielding stress.

For the second design the disadvantage of this design is: that it has 4 dead points, and these dead points affect the camera view, so not all regions will be viewed.

For the third design the disadvantage of this design are: the design simplicity, as seen this design is fully of drillings, threads, and screws, so this will cause stress consternation, and this maybe break transparent material or make it weak, and this affect the toughness of the case.

From these three designs, the fourth design is came out to be the suitable one between the others designs, that because it is satisfy the functional specification for the CUC project.

2.3 Mechanical Calculations

2.3.1 Buoyancy Force

It is a common experience that an object feels lighter and weighs less in a liquid than it does in air. This can be demonstrated easily by weighing a heavy object in water by a waterproof spring scale. Also, objects made of wood or other light materials float on water. These and other observations suggest that a fluid exerts an upward force on a body immersed in it. This force that tends to lift the body is called the buoyant force and is denoted by $\boldsymbol{F_B}$. One of the oldest known scientific researches on fluid mechanics relates to buoyancy due to question of money was carried by Archimedes. Archimedes principle is related to question of density and volume.

Archimedes principle says: The buoyant force acting on a body immersed in a fluid is equal to the weight of the fluid displaced by the body, and it acts upward through the centroid of the displaced volume.[2]

The total forces the liquid exacts on a body are considered as a buoyancy issue to understand this issue, consider a cubical body that is immersed in liquid and center in a depth of h_0 as shown in Fig.2.6.

The force to hold the cylinder at the place must be made of integration of the pressure around the surface of the square and cylinder bodies. The forces on square geometry body are made only of vertical forces because the two sides cancel each other. However, on the vertical direction, the pressure on the two surfaces is different. On the upper surface the pressure is

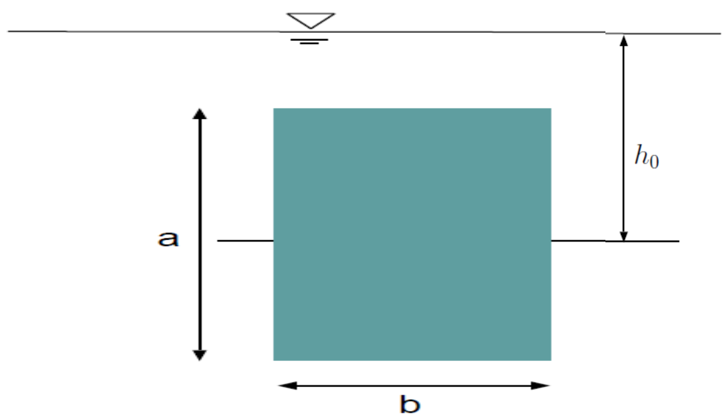

Figure 2.6 Front View of Immersed Cube

$$P_{Upper} = \rho\, g\, (h_0 - a/2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2.1)$$

Where P the upper surface the pressure, ρ is the fluid density, g is the Gravitational acceleration, h_0 is the center in a depth, and a is the cube height.

On the lower surface the pressure is

$$P_{Lower} = \rho\, g\, (h_0 + a/2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots. (2.2)$$

The force due to the liquid pressure per unit depth (into the page) is

$$F_B = F_{Upper} - F_{Lower} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

$$F_B = \rho\, g\, \big((h_0 + a/2) - (h_0 - a/2)\big)\, l\, b = \rho\, g\, a\, b\, l = \rho\, g\, V \quad \ldots.\ldots\ldots\ (2.4)$$

Where F_B is the buoyancy force, b is the width of the cube, l is the depth of the cube, and V is the volume of the cube.

The force on the immersed body is equal to the weight of the displaced liquid. This analysis can be generalized by noticing two things. All the horizontal forces are canceled. Anybody that has a projected area that has two sides, those will cancel each other.

Another way to look at this point is by approximation. For any two rectangle bodies, the horizontal forces are canceling each other. Thus even these bodies are in contact with each other, the imaginary pressure makes it so that they cancel each other.

When a body is totally immersed in water it displaces an amount of water equal to its body volume. If the weight of the displaced water is greater than the weight of the body, the body is said to be positively buoyant and will tent to float.

If the weight of the water less than that of the body, the body is said to be negatively buoyant and will tent to sink. If the weight of the displaced water equals to the body weight, the body neutrally buoyant.

Buoyancy: is an upward force exerted by a fluid that opposes the weight of an immersed object.[3]

It's known that the mass equal to the density multiplies by the volume

$$m = \rho V \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.5)$$

Where m is the mass, V is the volume, ρ is the material density, and m is the mass, and it is equal to

$$w_1 = m_1 g \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.6)$$

,and Newton's second law is

$$\sum F = ma \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.7)$$

where a is the acceleration of the body, and acceleration of the equilibrium (static) body equal zero ($a = 0$), the substitution of the acceleration in equation 2.7 this will give

$$\sum F = 0 \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.8)$$

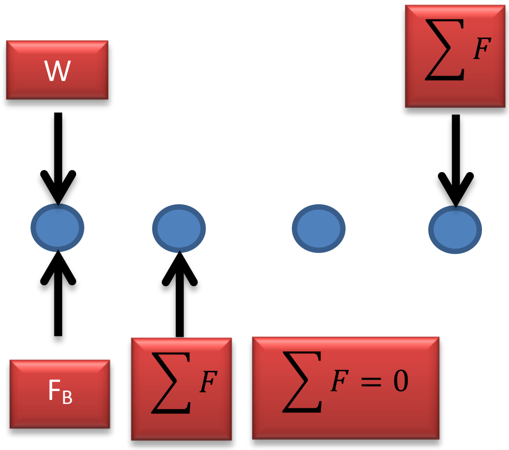

Figure 2.7 Forces Acting On The Body, And The Forces Summation In Positive, Neutrally And Negative Buoyant Statue Of The Body

The forces acting on the body are the weight downward and the bouncy force upward, so equation 2.8 will be

$$w - F_B = 0 \quad \dots \quad (2.9)$$

If $w < F_B$ the resultant force direction is with the buoyancy force direction which it is upward, so the body will be positively buoyant.

If the weight equal to bouncy force $(w = F_B)$ the body will be in the neutrally buoyant statue.

To ensure that the body in the negative buoyant state, the weight must be greater than the buoyancy force from the displaced volume.

$$w_t > F_B \quad \dots \quad (2.10)$$

$$m_t\, g > m_{water}\, g \quad \dots \quad (2.11)$$

$$m_t > m_{water} \quad \dots \quad (2.12)$$

by substitution equation 2.5 in equation 2.12 this give

$$m_t > \rho_{water} V_{t\ displaced} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (2.13)$$

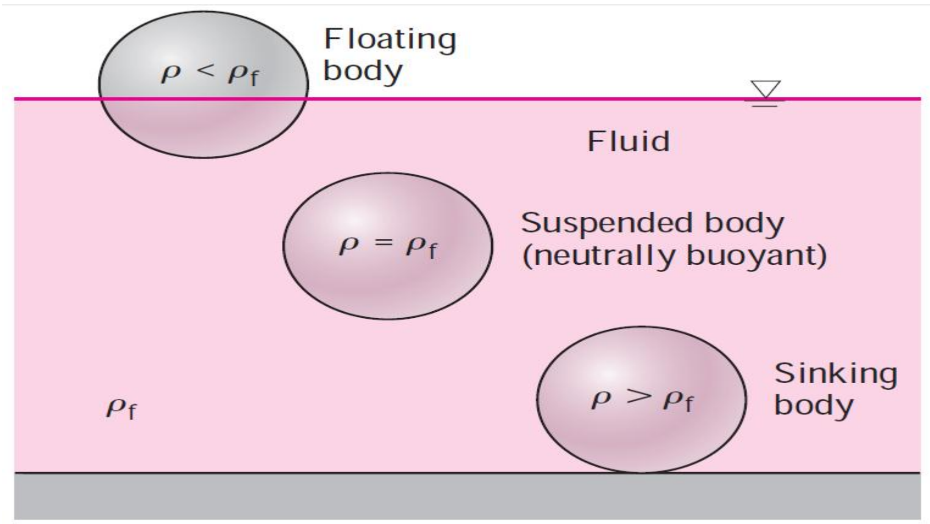

Figure 2.8 A Solid Body Dropped Into A Fluid Will Sink, Float, Or Remain At Rest At Any Point In The Fluid, Depending On Its Density Relative To The Density Of The Fluid.[3]

so the total volume must calculated to calculate the total mass, and make it bigger than the displaced mass of water.

The first component of the design is hollow cylinder as shown in Fig 2.9 case made from Plexiglas, its outer diameter $(D) = 90$ mm and its inner diameter $(d) =$ 85 mm, and height (h) = 150 mm, so it's volume (V_t) equal to

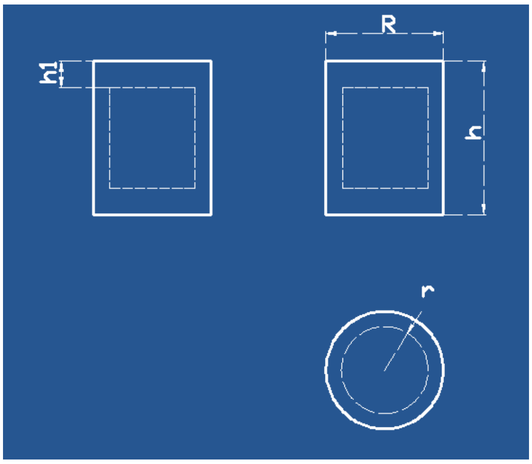

Figure 2.9 Right, Front and Top Views Of The Vessel of the Camera First Component.

$$V_t = V + V_1 + 2(V_2)$$

Where V is the hollow cylinder volume, V_1 is the volume of hollow in the cylinder, V_2 is the volume of the upper and the lower cover part.

$$V = \pi \ h \left(\frac{D^2}{4} - \frac{d^2}{4}\right) \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2.14)$$

$$V = \pi \ (0.15) \ \left(\frac{0.09^2}{4} - \frac{0.085^2}{4}\right)$$

$$V = \ 1.0308^{-4} \ [m^3]$$

The volume of hollow in the cylinder is equal to

$$V_1 = \pi \ h \ \frac{D^2}{4} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2.15)$$

$$V_1 = \pi \ (0.15) \left(\frac{0.085^2}{4}\right)$$

$$V_1 = \ 7.5398^{-4} \ [m^3]$$

,and the second component is upper and lower mechanical cover as shown in Fig.2.10 made from Poly vinyl chloride(PVC), it's has outer diameter (D_1) = 130 mm and height (h) = 20 mm, by substitution in equation 2.15 it's volume (V) equal to

$$V_2 = \pi \ h \ \frac{D^2}{4}$$

$$V_2 = \pi \ (0.02) \left(\frac{0.13^2}{4}\right)$$

$$V_2 = 2.6546^{-4} \ [m^3]$$

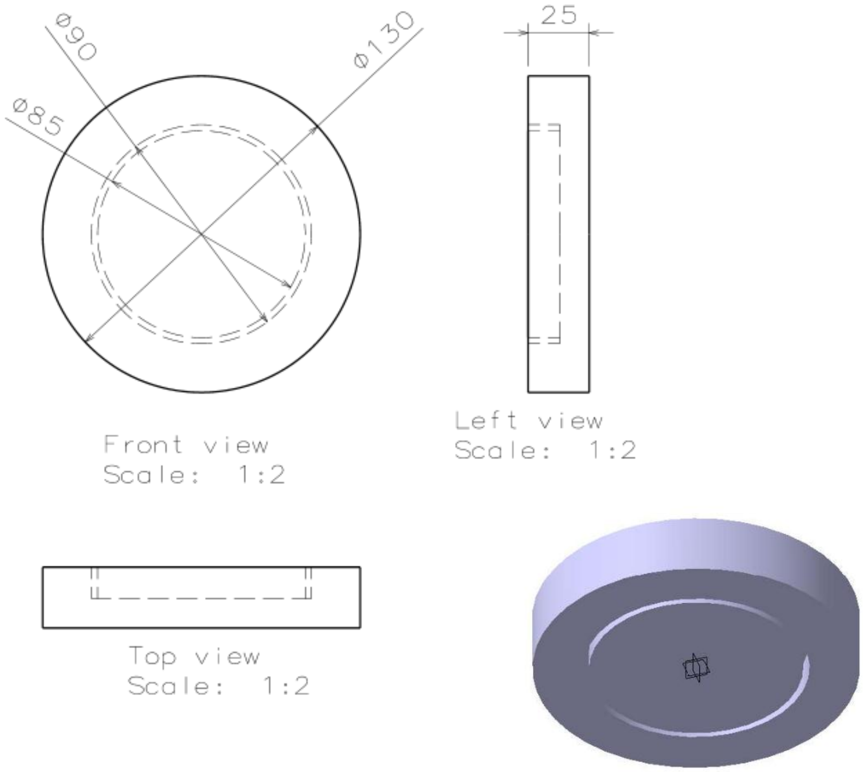

Figure 2.10 Front, Left, Top View, And Three Dimension Shape For Upper And Lower Cover

So the total volume equal to

$$V_t = V + V_1 + 2(V_2) = 1.0308^{-4} + 7.5398^{-4} + 2(2.6546^{-4})$$

$$V_t = 13.8798^{-4} = 1.38798^{-3}\ [m^3]$$

The density of air $1.225\ kg/m^3$, the density of Plexiglas (Acrylic) $1400 kg/m^3$, the density of water $1000\ kg/m^3$, and the density of Poly vinyl chloride(PVC) is $1200\ kg/m^3$.

By substitution the density and the volume of displaced water in equation 2.5, the mass of the water is equal to

$$m_{water} = \rho V_t = 1000(1.38798^{-3}) = 1.38798\ [Kg]$$

By substitution the density and the volume of each material in equation 2.5 total mass of the designed case is equal to

$$m_t = \rho \mathrm{V} + \rho_1 \mathrm{V}_1 + 2\ \rho_2 \mathrm{V}_2$$

$$m_t = 1400\ (1.0308^{-4}) + 1.225\ (7.5398^{-4}) + 2(1200)(2.6546^{-4})$$

$$m_t = 0.782\ [Kg]$$

By comparing the total mass and the mass of the displaced water, the mass of displaced water is bigger $m_t < m_{water}$, so the case body will float.

To decrease the floating force two choices available the first one is increase the mass of the total case and the second one is decrease the hollow diameter, or increase the outer diameter.

The second and the third choice is not compatible with this project, because the mass for hollow cylinder Plexiglas material is less than the mass of the displaced water unless the inner diameter is decrease, and this decrease will make the possibility for enter any thing of the project components impossible, so the first choice is the logical choice.

So the mass of the total case will be increased by adding mass in the case. To compute the volume of the added mass the mass of the displaced volume, and material type of added mass must be known.

The total volume is calculated, and the material must be selected.

The total mass equal to the case body and the added mass body

$m_t = m_{case\ body} + m_{added\ mass}$

$m_{added\ mass} = m_t - m_{case\ body}$

$m_{added\ mass} = 1.38798 - 0.782\ =\ 0.6058\ [Kg]$

The added mass must be greater than $m_{added\ mass}(0.6058\ [Kg])$.

$F_B = \left(m_t - m_{case\ body}\right)g$

$F_B = m_{added\ mass}g = 0.6058(9.81) = 5.942898\ [\ Newton]$

The selected volume shape for this added mass is cylinder, because it's easy to turning, lathing, drilling, and milling.

The selected material is steel because it's available in the workshops and salvage stores, and it's legal to sale and buy to the nongovernmental people.

From equation 2.5 the volume equal to

$$V = \frac{m}{\rho} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (2.17)$$

$$V = \frac{0.6058}{7600} = 7.92^{-5} [m^3]$$

substitution V= 7.92^{-5} m^3 and $d =$ 84 mm, to ensure that the added mass enter the hollow in the Plexiglas cylinder in equation 2.16

$$h = \frac{V_1}{\pi \frac{d^2}{4}} = \frac{7.92^{-5}}{\pi \frac{0.084^2}{4}} = 0.014291 \; [m]$$

$$h = 1.4291 \; [cm]$$

this height will make the system neutrally buoyant, so the height of the added mass must be greater than 1.4291 cm.

An important application of the buoyancy concept is the assessment of the stability of immersed and floating bodies with no external attachments. This topic is of great importance in the design of ships and submarines.

2.3.2 Stability

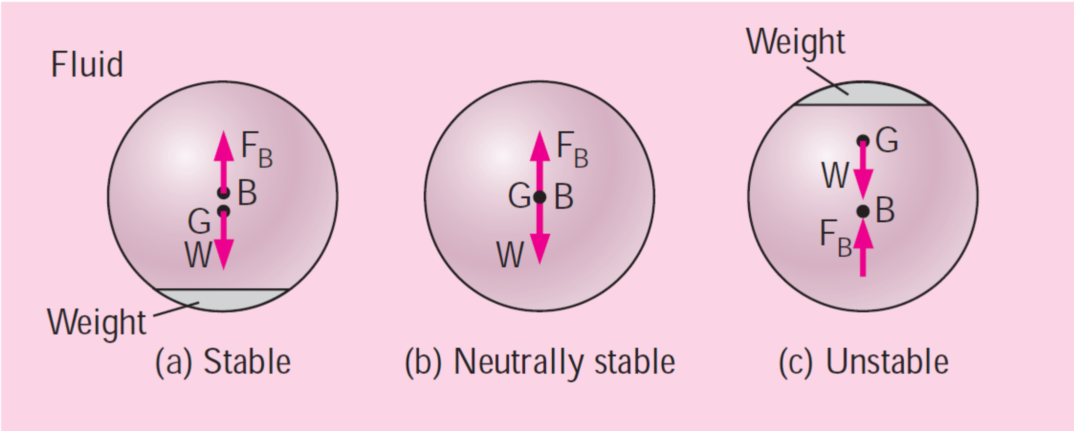

Figure 2.11 An Immersed Neutrally Buoyant Body Is (A) Stable If The Center Of Gravity G Is Directly Below The Center Of Uoyancy B Of The Body, (B) Neutrally Stable If G And B Are Coincident, And (C) Unstable If G Is Directly Above B.[4]

A floating object is stable if it tends to restore itself to an equilibrium position after a small displacement. For example, floating objects will generally have vertical stability, as if the object is pushed down slightly, this will create a greater buoyancy force, which, unbalanced by the weight force, will push the object back up.

The rotational stability of an immersed body depends on the relative locations of the center of gravity **G** of the body and the center of buoyancy **B**, which is the centroid of the displaced volume. An immersed body is stable if the body is bottom-heavy and thus point G is directly below point B is sufficiently far, these two forces create a restoring moment and return the body to the original position.[3]

A measure of stability for floating bodies is the metacentric height **GM**, which is the distance between the center of gravity **G** and the metacenter **M**—the intersection point of the lines of action of the buoyant force through the body before and after rotation. The metacenter may be considered to be a fixed point for most hull shapes

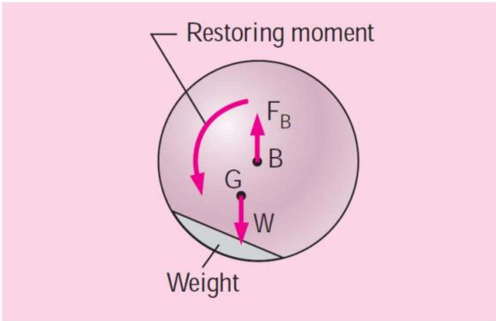

Figure 2.12 When The Center Of Gravity G Of An Immersed Neutrally Buoyant Body Is Not Vertically Aligned With The Center Of Buoyancy B Of The Body, It Is Not In An Equilibrium State And Would Rotate To Its Stable State, Even Without Any Disturbance.[3]

for small rolling angles up to about 20°. A floating body is stable if point M is above point G, and thus GM is positive and unstable if point M is below point G, and thus GM is negative. In the latter case, the weight and the buoyant force acting on the tilted body generate an overturning moment instead of a restoring moment, causing the body to capsize. The length of the metacentric height GM above G is a measure of the stability: the larger it is, the more stable is the floating body.

To make GM positive and ensure that the system is stable the added mass to the vessel camera system must be under the vessel not in the top.[3]

$$\frac{\bar{x}}{\tan\theta} = \overline{MB} = \frac{I_O}{V_{submerged}} = \overline{MG} + \overline{GB} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.18)$$

or $\overline{MG} = \frac{I_O}{V_{sub}} - \overline{GB}$

The center of gravity **G** with respect to the x, y and z axes:

$\bar{x} = 0$

$\bar{y} = 0$

$$\bar{z} = \frac{1}{2}h$$

The engineer would determine the distance from G to B from the basic shape and design of the floating body and then make the calculation of I_O and the submerged volume sub. If the metacentric height MG is positive, the body is stable for small disturbances. Note that if is negative, that is, B is above G, the body is always stable.[3]

The added mass will placed in the bottom of the case to ensure that the system is stable.

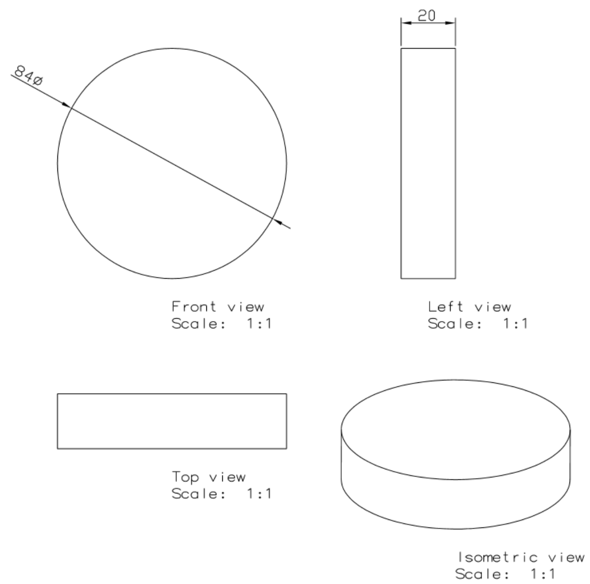

Figure 2.13 Front, Left, Top, And Isometric View For Added Mass.

Design versus Stability:

The position of the center of gravity of an object affects its stability. The lower the center of gravity (G) is the more stable the object. The higher it is the more likely the object is to topple over if it is pushed.

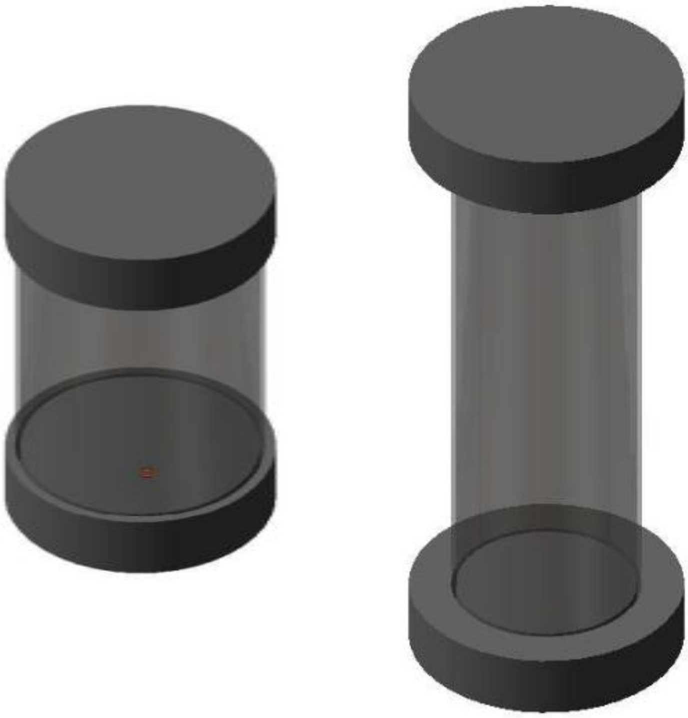

Figure 2.14 Two Different Dimension For The Same Design Shape.

Increasing the area of the base will also increase the stability of an object, the bigger the area the more stable the object depending on the following rule that say.

"If an object is tilted it will topple over if a vertical line from its center of gravity falls outside its base."[4]

2.3.3 Insulation

The material used in CUC insulation is:1) Plexiglas(Acrylic) 2) PVC 3)Silicon

Plexiglas (Acrylic) which has the following properties:

- Excellent light transmission and brilliance
- Outstanding weather resistance
- High surface hardness
- Light weight – half of the weight of glass
- 100% recyclable
- 11 times more break resistant than glass

Silicon which has the following properties:

Figure 2.15 Silicon Glue

- Low chemical reactivity
- Low toxicity
- Thermal stability (constancy of properties over a wide temperature range of -100 to 250 °C.
- The ability to repel water and form watertight seals.
- Does not stick to many substrates, but adheres very well to others, e.g. glass.
- Electrical insulation properties. Because silicone can be formulated to be electrically insulate or conductive, it is suitable for a wide range of electrical applications.

2.3.4 Drag Force

A fluid may exert forces and moments on a body in and about various directions. The force a flowing fluid exerts on a body in the flow direction is called drag**.**
To calculate the drag force the type, speed, and Reynolds number for the fluid must be known.

For Reynolds number greater than 10^4 $F_D = C_D A \rho V^2/2$ … … … … … … … (2.19) [5]

where F_D is the drag force, C_D is the drag coefficient, A is the area which the fluid drag it, ρ is the density of fluid, and V is the upstream velocity.

In equation 2.19 the density, and the area are known, but the drag coefficient and the velocity are unknown. To calculate the drag coefficient for equation 2.19 the Reynolds number must be greater than 10^4

$$Re = \frac{\rho V D}{\mu} \quad \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.20)$$

where ρ is the density, V is the velocity, D is the diameter, and μ is the viscosity.

In the Reynolds equation all the variable is known except the velocity, so the velocity will be assumed. Assumed that the minimum speed equal to $0.2\ \frac{m}{s}$, and the maximum speed equal to $5\ \frac{m}{s}$.

For water at 5 ^{o}C $\rho = 1000\ \frac{Kg}{m^3}$, and $\mu = 1.519\ (10^{-3})\frac{N.s}{m^2}$. [6]

Assume that the water temperature equal to5 ^{o}C, so for minimum speed in the water

$$Re = \frac{\rho VD}{\mu} = \frac{(1000)\ (0.2)(0.13\ )}{1.519\ (10^{-3})} = 1.7(10^4),$$

and for maximum speed in the water

$$Re = \frac{\rho VD}{\mu} = \frac{(1000)\ (5)(0.13\ )}{1.519\ (10^{-3})} = 6.5(10^5),$$

so in this region the Reynolds number is greater than 10^4 and less than 10^7.

For the case in CUC system, it's the same case for short horizontal cylinder [5] which has $\frac{L}{D}$ equal to 2, where L is the length of cylinder, and D is the diameter for cylinder.

This give coefficient of drag $C_d =\ 0.9$.

The cable which handle the CUC system maximum allowable tension load is $100\ N$,

Assume the velocity is constant From Fig.2.15 and equation 2.8 the maximum allowable tension load is equal to

$$\sum F = 0$$

$$MATL - F_D - (F_B\ - w) = 0$$

$$MATL = F_D + F_B\ - w \ldots\ldots\ldots\ldots\ldots\ldots (2.21)$$

where $MATL$ is the maximum allowable Force, F_D is the drag force F_B is the buoyance force, and w is the weight of the CUC system.

so the allowable drag force from eq.2.21 is equal to

$$F_D = MAL - F_B + w = 100 - 25 + 20 = 95\ N$$

From equation 2.19 the maximum allowable speed for CUC system is equal to

$$V = \sqrt{\frac{2\,F_D}{C_D A \rho}} = \sqrt{{2\,(95)}/{0.9(0.0133)(1000)}} = 3.9\ \frac{m}{s}.$$

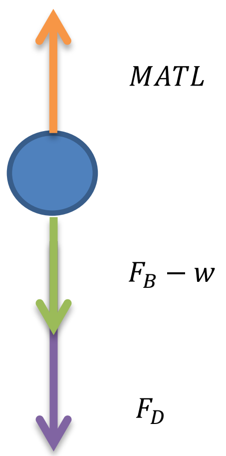

Figure 2.16 Free Body Diagram for CUC System when someone drag it

Chapter Three

Electrical Component Selection and Calculations

3.1 Electrical Parts

3.1.1 Micro-controller (μC)

3.1.2 Actuator

3.1.3 Position Sensor

3.1.4 Power Circuit

3.1.5 Liquid Crystal Display (LCD)

3.1.6 Switches

3.1.7 Operational Amplifier (OPAMP)

3.1.8 Temperature Sensor

3.1.9 Voltage regulator

3.1.10 Light Emitting Diode Lighting (LED Lighting)

3.2 Electrical Calculations

3.2.1 Electrical losses

3.2.2 Transformer Ratings

3.3 Whole System Diagram

The selection of components is based on a concurrent approach rather than a sequential approach. In other words, the components are chosen after an involved study of the requirements for the electronics, mechanical, electrical communication and interfacing parts.

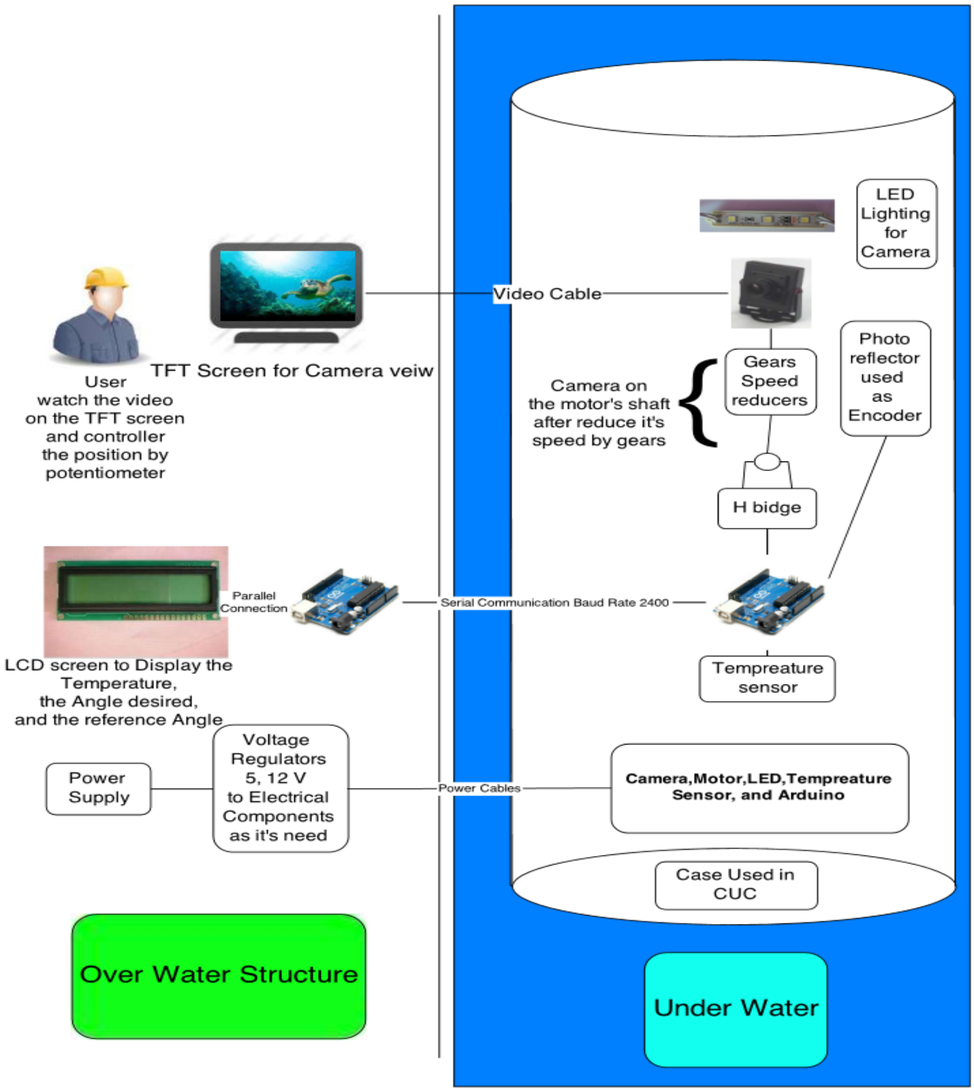

Figure 3.1 Main Components of CUC project.

3.1 Electrical Parts

3.1.1 Micro-controller (µC)

The chosen micro-controller is Arduino Uno as shown in Fig.3.2 It has many advantages that make it the preferred choice such as: user friendly, open source codes which are available for many applications and can be downloaded from the company's website, the simulation program, the upgradability, the modularity and the last important thing is that, it does not need a dedicated programmer as it can be programmed through the same cable that is used for the PC connection

The Arduino Uno is a microcontroller board based on the ATmega328

Specification

- Microcontroller ATmega328
- Operating Voltage 5V DC
- Input Voltage (recommended) 7-12V DC
- Digital I/O Pins 14 (of which 6 provide PWM output)

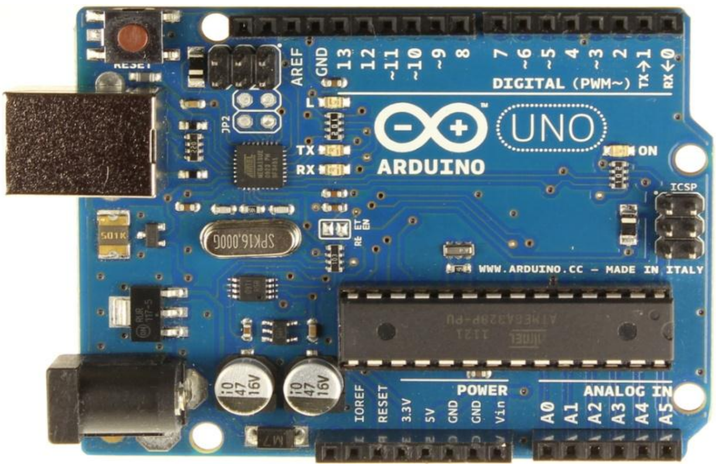

Figure 3.2 Arduino Uno board.

- DC Current per I/O Pin 40 mA DC
- DC Current for 3.3V Pin 50 mA DC
- Clock Speed 16 MHz [7]

3.1.2 Actuator

A DC motor is a mechanically commutated electric motor powered from direct current (DC). The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems called DC drives.

DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles. Today DC motors are still found in applications as small as toys and disk drives, or in large sizes to operate steel rolling mills and paper machines. [8]

Figure 3.3 Real D.C motor

Motor specification without gear used in CUC.

Torque [N.m]	Speed [rad/s]	Voltage[volt] DC	Current [mA] DC
0.001	220	5	300

3.1.3 Position Sensor

The most common angular position sensors are encoders and potentiometers. These two types are chosen as the first decision to be studied. Potentiometers are chosen first as they are simple in structure, inexpensive and relatively accurate comparable

Figure 3.4 Non-Linear potentiometer

Figure 3.5 Linear Increment Potentiometer

Figure 3.6 Rotary Encoder

to the other inexpensive sensors. The required potentiometers' resistance should be linearly changed as the change in the position. The problem is the lack of this type of potentiometers in the domestic market and that the available potentiometers are nonlinear as the one shown in Fig.3.4. Tests are performed using these nonlinear potentiometers and the results are unaccepted for two reasons. First of all, the accuracy is bad. The second reason is that, the hand's position which corresponds to the coordination of the manipulator which is mapped on the screen is shacking all the time even if the manipulator is fixed. After that, the eyes are on rotary encoders. Encoders have two types: absolute encoders and incremental encoders as the one shown in Fig.3.6. The advantage of using the absolute encoder over the incremental one appears in case of the power which supplies the encoder is lost. An absolute encoder can continue from the position which it lies on even if it is changed during the power lost. While the incremental encoder starts counting from zero. For this reason, the absolute encoder is double in the price relative to the incremental one.

The required incremental encoder should satisfy some requirements such as: the number of pulses per revolutions, the size and the input/output voltage. As the number of pulses increase, the accuracy increases. The available encoders in the stores are 300, 500, 1000 pulse/rev. the first two types have the same price, so the appropriate choice is the one with the higher accuracy as the 300 pulse/rev is equivalent to 1.2 degrees for each pulse and the 500 pulse/rev is equivalent to 0.72 degree.

Another problem appears in the input/output voltage. The input voltage is 12v DC so an external power supply is needed other than the Arduino which supplies 5v DC only. The output voltage is 12v DC which needs voltage regulator for each channel of each encoder to be at the normal range of the Arduino input voltage. Tests are performed on this type of encoder with an external power supply and the common voltage regulator (7805). It has been found that, these regulators are not applicable for encoders since they are slow in voltage regulation and that the encoders have a huge number of pulses. The solution is using optocouplers transistors or using an encoder with the same specifications as the previous one except the input/output voltage is 5v DC. This encoder is double of the 12v input/output price.

There is an electrical device can be used as encoder, it's the photo reflector, this device contain photo transmitter and receiver as shown in Fig.3.7, and it's recognize if there is change in the color of the sensing element, this phenomenon can be used as

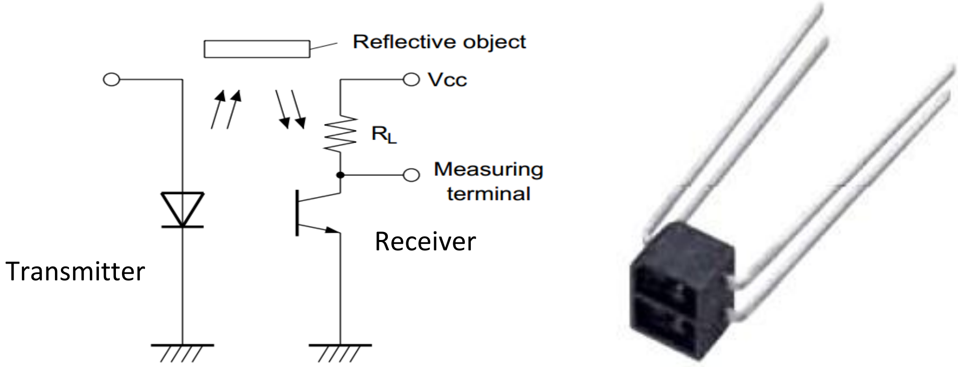

Figure 3.7 Electricial Schemetic And Read Veiw For The Photo-Reflector

encoder if we put another different color of the second gear, so this will generate pulses every revolution.

This photo reflector is inexpensive, accurate, and compatible with Arduino.

Photo reflector specifications used in CUC.

Input (Transmitter) Specification		
Supply Voltage [volt]	Current [mA]	Power Dissipation [mW]
5	50	75

Output (Receiver) Specification		
Supply Voltage [Volt] DC	Current [mA] DC	Power Dissipation [mW] DC
6	20	75

Total Power Dissipation [mW]	Operation Temperature [^{o}C]
100	-25 to +85 [9]

3.1.4 Power Circuit (H Bridge)

H Bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards.[10]

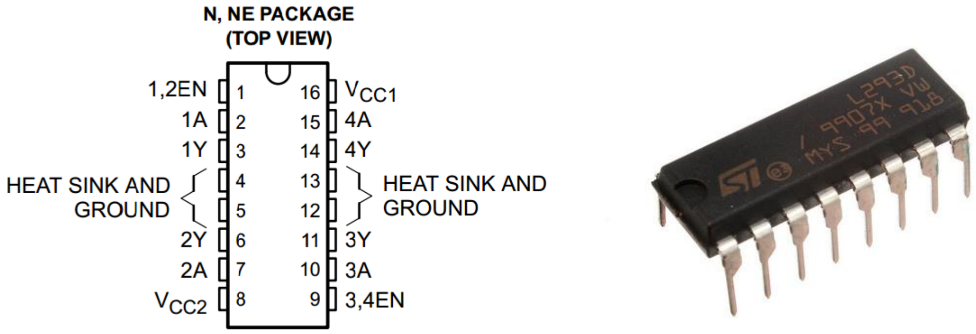

Figure 3.8 Electricial Schemetic And Read Veiw For L293 Hbridge [11]

It’s called an H-Bridge, because it’s shaped like an H, with the motor in the very middle as shown in the Fig.3.9.

H-bridges are available as integrated circuits, or can be built from discrete components. The term H-bridge is derived from the typical graphical representation of such a circuit. An H bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 according to Fig.3.9 are closed (and S2 and S3 are open) a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor.

The H-bridge arrangement is generally used to reverse the polarity of the motor. Using the nomenclature above, the switches S1 and S2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S3 and S4. This condition is known as shoot-through.

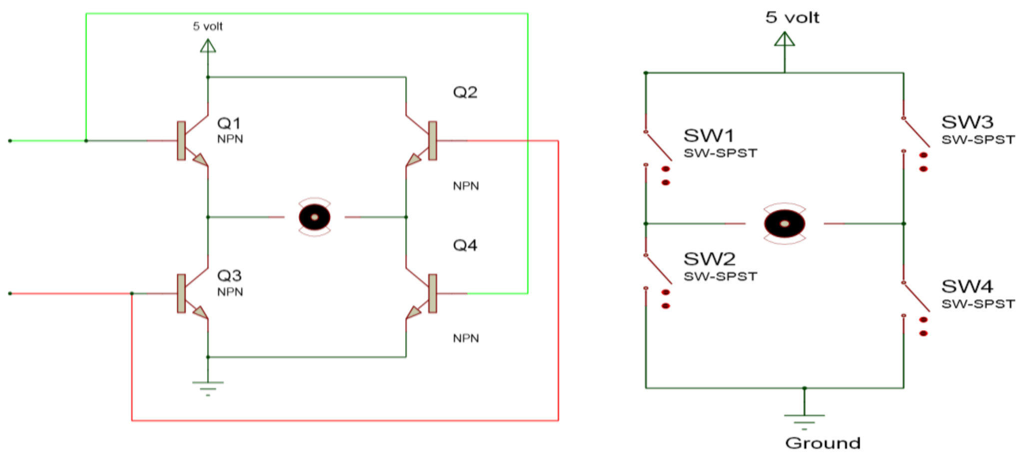

Figure 3.9 Hbridge Using Transistors and switches

In every device there is advantages and disadvantages, however the advantages of H-bridge are:

- No periodic maintenance is required (no contacts)
- Fast switching speed available (limited by motor)

, and the disadvantage is: limited voltage and current handling capacity.

H-bridge specifications used in CUC.[11]

Supply Voltage [volt] DC	Output Voltage[volt] DC	Current Per Channel [mA] DC	Operation Temperature [^{o}C]
V_{cc1}=4.5 to 7 V_{cc2}= V_{cc1} to 36	4.5 to 36	600	0 to 70

3.1.5 Liquid Crystal Display (LCD)

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred on seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x8 pixel matrix as shown in Fig.3.10.

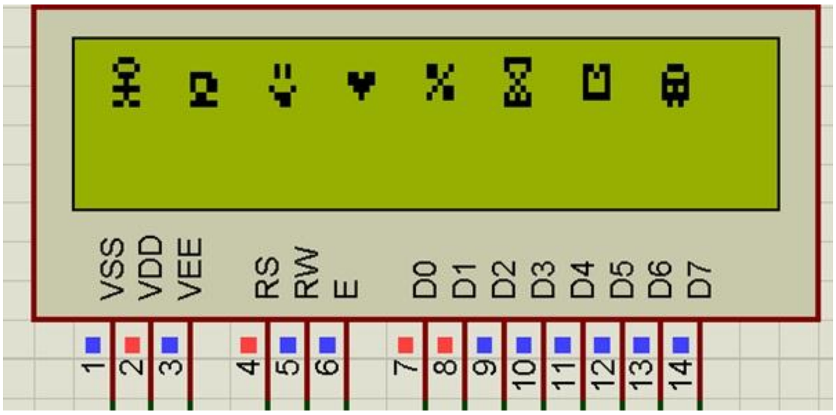

Figure 3.10 LCD Pins And Simulation Of Special Character.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

The normal operation for LCD is the parallel way8 bit A0 to A7 or 4 bit A4 to A7.

The first way of sending data is the 8 bit operation in this way the data sends as 8 bit (1 byte), however the second way is the 4 bit operation sends the 8 bit as 2 nibble each one alone then the LCD itself waits until the first and the second nibble sent so the 8 bit complete and analysis the 8 bit and makes the output massage on the screen.

LCD specifications used in CUC.[12]

Supply Voltage [volt] DC	Supply Current [mA] DC	Backlight Supply Current [mA] DC	Operation Temperature [^{o}C]
5	2.5	16	0 to 60

3.1.6 Switches

In electrical engineering, a switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another.

The most familiar form of switch is a manually operated electromechanical device with one or more sets of electrical contacts, which are connected to external circuits. Each set of contacts can be in one of two states: either closed meaning the contacts are touching or electricity can flow between them, or open, meaning the contacts are separated and the switch is non-conducting. The mechanism actuating the transition between these two states open or closed can be either a toggle flip switch as shown in Fig.3.11 or continuous on or off as shown in Fig.3.12 , or momentary push-for on or push-for off type.

Figure 3.11 Toggle Switch

Figure 3.12 On Off Switch

A switch may be directly manipulated by a human as a control signal to a system, such as a computer keyboard button, or to control power flow in a circuit, such as a light switch. Automatically operated switches can be used to control the motions of machines, for example, to indicate that a garage door has reached its full open position or that a machine tool is in a position to accept another work piece. Switches may be operated by process variables such as pressure, temperature, flow, current, voltage, and force, acting as sensors in a process and used to automatically control a system. For example, a thermostat is a temperature-operated switch used to control a heating process. A switch that is operated by another electrical circuit is called a relay. Large switches may be remotely operated by a motor drive mechanism. Some switches are used to isolate electric power from a system, providing a visible point of isolation that can be padlocked if necessary to prevent accidental operation of a machine during maintenance, or to prevent electric shock.

An ideal switch would have no voltage drop when closed, and would have no limits on voltage or current rating. It would have zero rise time and fall time during state changes, and would change state without bouncing between on and off positions.

There is many types of switches depending on number of inputs and outputs like as 1) **SPST** (Single pole, single throw): A simple on-off switch: The two terminals are either connected together or disconnected from each other. An example is a light switch as shown in Fig.3.13.

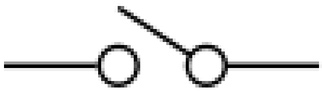

Figure 3.13 Electrical Schematic of SPST

2) **SPDT** (Single pole, double throw): A simple changeover switch: C (COM, Common) is connected to L1 or to L2 as shown in Fig.3.14.[13]

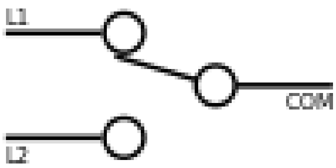

Figure 3.14 Electrical Schematic of SPDT

Two switches mentioned and there are more than two, but these two are the types used in CUC project.

Toggle and on off switches specifications used in CUC.[14]

Max. Voltage [volt] AC	Max. Current [A] AC
250	15

3.1.7 Operational Amplifier (OPAMP)

An operational amplifier (op-amp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.

Op-amps are among the most widely used electronic devices today, being used in a vast array of consumer, industrial, and scientific devices. Many standard IC op-amps cost only a few cents in moderate production volume; however some integrated or hybrid operational amplifiers with special performance specifications may cost over $100 US in small quantities. Op-amps may be packaged as components, or used as elements of more complex integrated circuits.[15]

The OPAMP has many uses in our life in 1) signal processing such as amplification, filtering, and summing, etc., and 2) controlling in traditional way such as proportional, integral, and derivative controllers.

In this project the OPAMP is used as comparator.

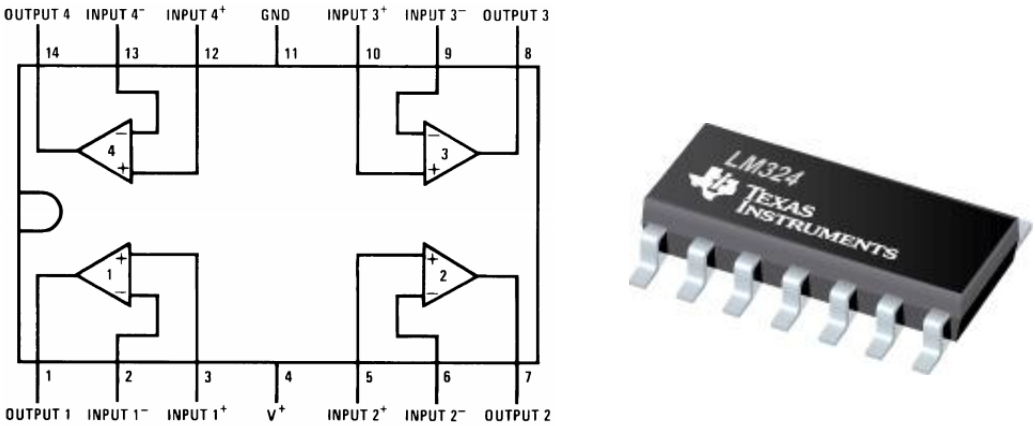

Figure 3.15 Internal Block Diagram and real OPAMP [16]

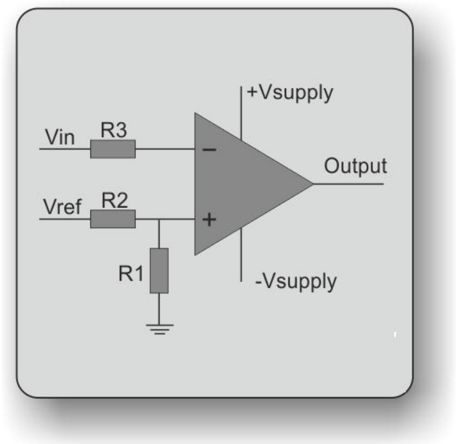

Figure 3.16 OPAMP Used As Comparator

3.1.8 Temperature Sensor

A temperature: is a numerical measure of hot and cold. It may be calibrated in any of various temperature scales, Celsius, Fahrenheit, Kelvin, etc.

Many methods have been developed for measuring temperature. Most of these rely on measuring some physical property of a working material that varies with temperature such as thermocouple, resistance temperature devices (RTD), thermistors, and Infrared thermometer.

Why we must measure the temp in this project, because in this project the electronics and electrical devices have a range temperature can work in it with in normal way, if the temperature value is get out of this range the device maybe broken or damage, so we need to constrain the temperature in this range by measuring the temperature and turn of the components which increase the temperature such as the regulator and the motor.

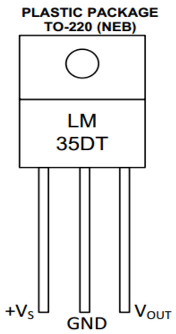

Figure 3.17 Front veiw for tempeature sensor Lm 35

The most common temp range for electrical and electronics devices is 0 ^{o}C to 50 ^{o}C, and the measuring value range for the temperature sensor LM35 is -55 ^{o}C to 150 ^{o}C, so this sensor is suitable for this project.[17]

There are many advantage and reasons for using LM35 temperature sensor: 1) the suitable range of temperature, 2) Linear +10 mV / ^{o}C scale factor, 3) low cost.

3.1.9 Voltage regulator

A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed-forward" design or may include negative feedback control loops. It may use an electromechanical mechanism, or electronic

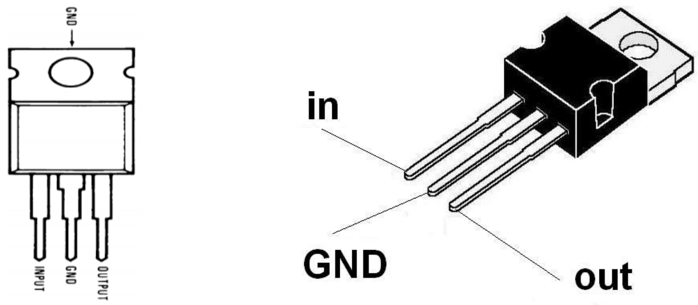

Figure 3.18 Top veiw for voltage regulator and voltage regulator pins.

components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

Electronic voltage regulators are found in devices such as computer power supplies where they stabilize the DC voltages used by the processor and other elements. In automobile alternators and central power station generator plants, voltage regulators control the output of the plant. In an electric power distribution system, voltage regulators may be installed at a substation or along distribution lines so that all customers receive steady voltage independent of how much power is drawn from the line.

Regulators specifications used in CUC.[18]

Product Number	7805	7809	7812
Voltage [volt]	5	9	12
Current [Ampere]	1	1	1

3.1.10 Light Emitting Diode Lighting (LED Lighting)

A light-emitting diode (LED) is a semiconductor device that emits incoherent narrow-spectrum light when a p-n junction is forward electrically biased. LEDs are a very efficient form of energy production and have already come down in cost far enough to be competitive for a great number of applications such as traffic light. There are also white LEDs that can be used in place of incandescent light bulbs.

LEDs are an extremely efficient form of lighting. They produce far more light per watt than do incandescent bulbs - this is useful for energy conservation, but also extending the life of battery powered or energy-saving devices.

LEDs also have an extremely long life span. Philips has calculated the ETTF (Estimated Time To Failure) for their LEDs to be between 100,000 and 1,000,000 hours. However, most manufacturers rate their LED lifespan at 50,000 hours and some take a more conservative of 35,000 hours. This is due to the fact that after a certain number of active hours there is a fall-off in efficiency of the light, both in terms of lumen and color temperature, and while the light will still continue to operate, a user would probably want to replace them at that time.

Fluorescent tubes typically are rated at about 30,000 hours, CFL's or Compact Florescent Lights between 7,500 hours and 15,000 hours and incandescent light bulbs at 1,000-2,000 hours.

Unlike incandescent light bulbs, which light up regardless of the electrical polarity, LEDs will only light with positive electrical polarity. When the voltage across the $p-n$ junction is in the correct direction, a significant current flows and the device is said to be forward-biased. If the voltage is of the wrong polarity, the device is said to be reverse biased, and very little current flows, so no light is emitted. LEDs can be operated on an alternating current voltage, but they will only light with positive voltage, causing the LED to turn on and off at the frequency of the AC supply.

LED Lighting specifications used in CUC 0.72 watt 12 VDC

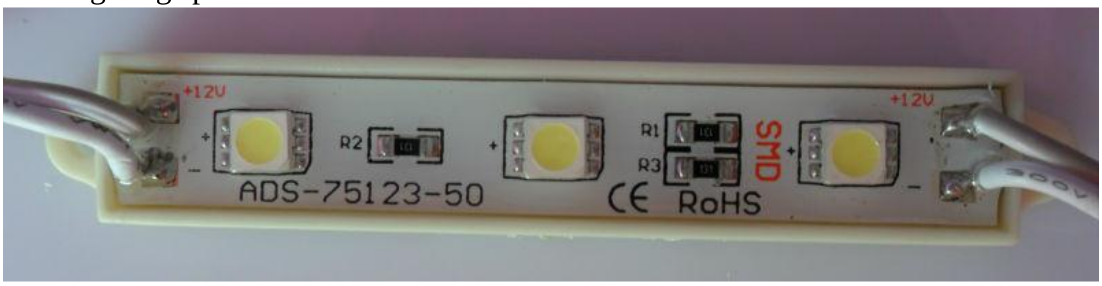

Figure 3.19 LED Lighting used in CUC 0.72 watt

Supply Voltage [Volt] DC	Supply Current [mA]
12	60

3.2 Electrical Calculations

The important of electrical calculation come from choosing power supply, voltage regulator, to overcome the electrical losses.

3.2.1 Electrical losses

In the engineer's life there is no system with 100% efficiency, there are losses in every system from the electrical, mechanical, electronics, and the hydraulic subsystems.

The efficiency in any system measure by the output power over (divided) the input power, so the electrical efficiency is defined as useful power output divided by the total electrical power consumed, therefore the electrical resistance must be calculated.

The electrical resistance of an electrical conductor is the opposition to the passage of an electric current through that conductor.

The resistance of a given object depends primarily on two factors: What material it is made of, its shape, and its length. For a given material, the resistance is inversely proportional to the cross-sectional area; for example, a thick copper wire has lower resistance than an otherwise-identical thin copper wire. Also, for a given material, the resistance is proportional to the length; for example, a long copper wire has higher resistance than an otherwise-identical short copper wire.

$$R = \frac{\rho L}{A} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (3.1)$$

Where R is the electrical resistance, or electrical wire resistance [Ω], ρ is the electrical resistivity [Ω. m], L is the total length [m], A is the area of the cable [m^2].

The most common of electrical wires is the copper wire, the electrical resistivity (ρ) for copper equals to $1.7*10^{-8}$ Ω. m.

In this project case the total length L equal to 40meter, and diameter equal to 0.5milimeter, because it's minimum cable diameter in IEC 60228 standard,

$$\mathrm{A} = \frac{\pi d^2}{4} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.2)$$

$$\mathrm{A} = \frac{\pi (0.5)^2 (10^{-3)})^2}{4} = 1.9635 * 10^{-7}\ m^2$$

the area equal to $1.9635 * 10^{-7} m^2$, so the electrical resistance equal to 3.4836 Ω .

This electrical wire resistance R will make drop voltage equal to

$$V_d = IR \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.3)$$

Where: V_d is the voltage drop [$volt$],I is the electrical current [$ampere$], and R is the electrical wire resistance [Ω]

The voltage drop will be unknown unless the current and the resistance is known.

If assumed that an electrical wire has input voltage in one of it is terminal and in the other terminal the voltage will be measured, the measured voltage will be equal to the drop voltage subtracted from the input voltage as shown in equation 3.4

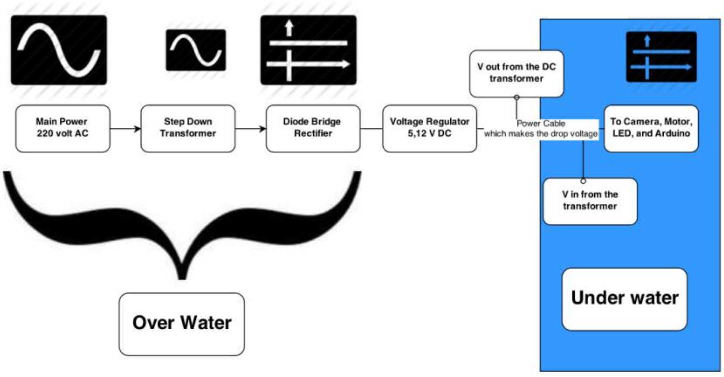

Figure 3.20 Chart shows the voltage out and voltage in in CUC.

$$V_{in} = V_{out} - V_d \qquad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3.4)$$

Where V_{out} the output voltage from the transformer is, V_{in} is the input voltage to the case, V_d is the voltage drop in the cable.

Form know what the electrical components needs in this project such as camera, motor, however other components could be neglected, because the power consumption compare to the main electrical power consumer in small, example the camera needs 1 $ampere$ and the motor needs 0.33 $ampere$, so the total power will almost equal to $1.5 amper$ ($I = 1.5\ ampere$).

so the voltage drop is known, because the voltage drop depend on the current and the resistance as shown in equation 3.3.

by substitution the current I and resistance R in equation. 3.4

$$V_d = IR$$

$$V_d = 1.5(\ 3.4836) \ = \ 5.2254\ volt.$$

To know the input voltage V_{in} to get the efficient transformer output

$$V_{out} \ = V_{in} + V_d \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3.5)$$

$$V_{out} \ = 12 + \ 5.2254 = 17.2254 \, volt$$

so 18 $volt$ 1.5 $ampere$ or higher transformer in voltage and current will needed in CUC project.

3.2.2 Transformer Ratings

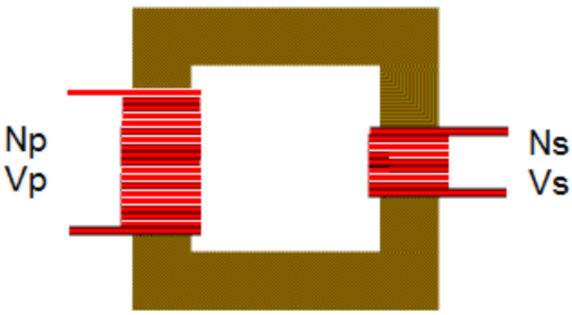

Figure 3.21 1 Phase Transformer

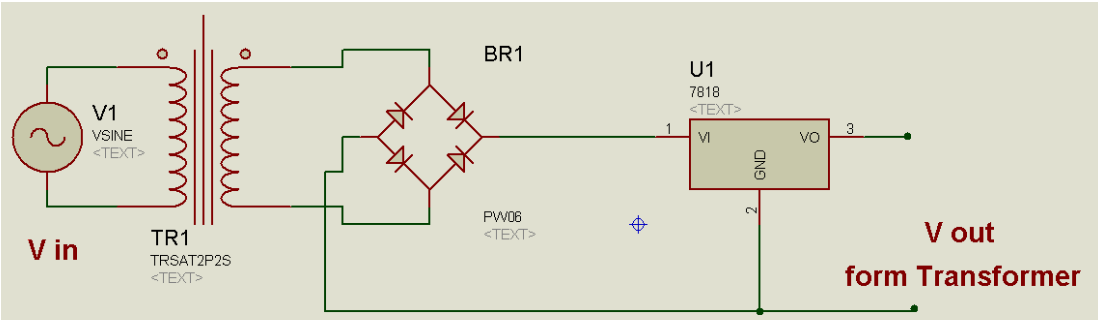

Figure 3.22 Transformer Cuircuit

$$V_p I_p = V_s I_S \quad \dots \dots \dots \dots \ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3.6)$$

where V_p is the primary transformer voltage, I_p is the primary transformer current, V_s is the secondary transformer voltage, and I_S is the secondary transformer current.

$$220I_p = 18(1.5)$$

$$I_p = \frac{18 * 1.5}{220} = 0.123\ A$$

$$S = V_p I_p = V_s I_S = 18 * 1.5 = 27\ VA$$

The most convenient transformer is $30\ VA$

3.3 Whole System Diagram:

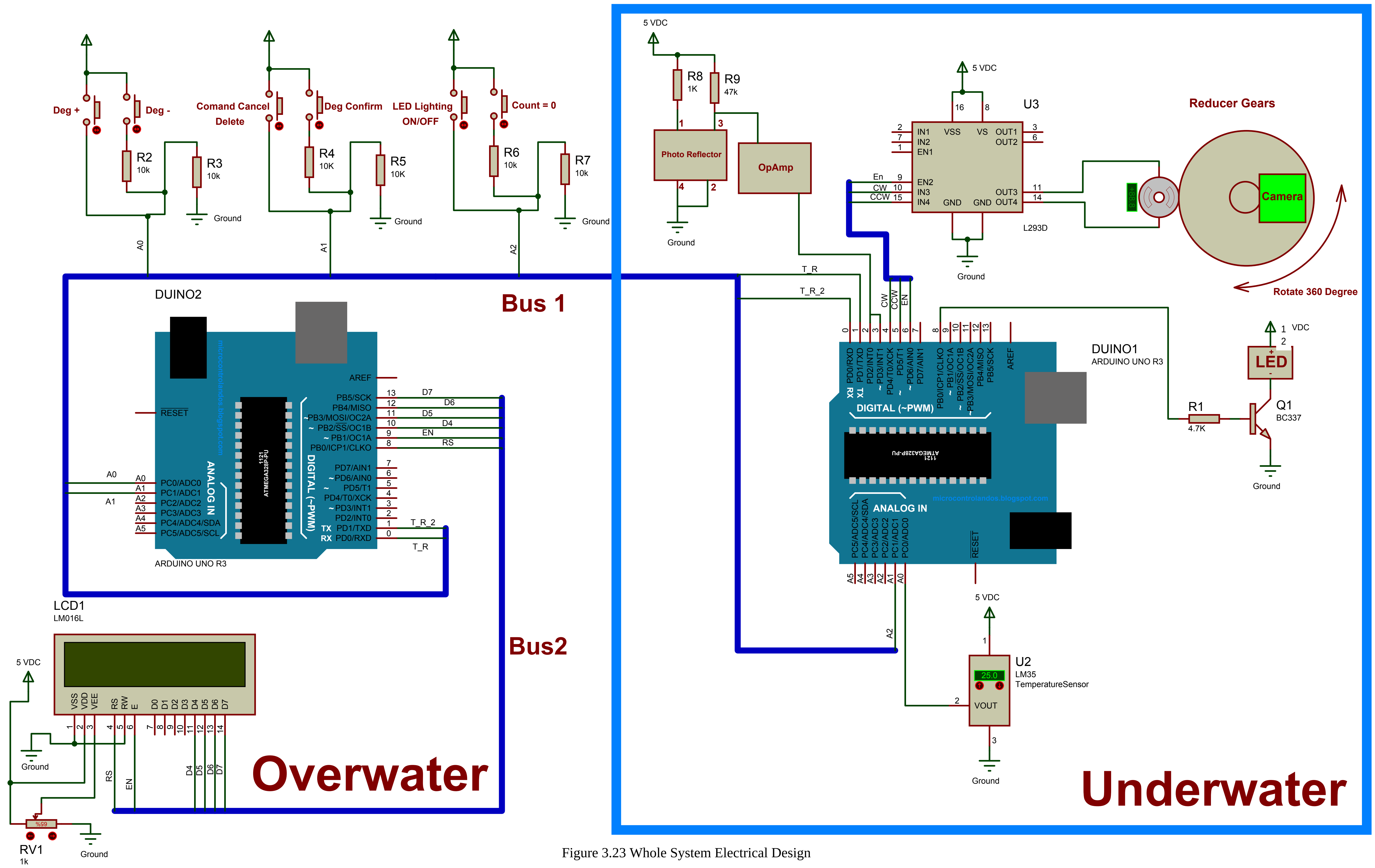

Figure 3.23 Whole System Electrical Design

Chapter Four

Modeling

4.1 Introduction

The dynamic performance of physical system is obtained by utilizing the physical laws of mechanical, electrical, fluid and thermodynamics systems. In general physical systems are modeled with nonlinear differential equations with constant or variable coefficients.

Mathematical modeling of CUC simple DC motor represent all important parameters that affect the behavior of the DC motor, and describe its behavior in terms of differential equation. Generally, a simplified model is needed to study the main characteristics of the system.

A basic model is derived for CUC simple DC motor which is simple and linear model for controller design and analysis purpose as accurately as possible. In the case of simple DC motor system, the following assumptions are used in deriving the mathematical model:

1. The controlling of simple DC motor done by two methods: the first one is controlling the voltage on the field circuit that called field-controlled DC-motor, another method is done by controlling the voltage on the armature of the DC-motor, so we called this method armature-controlled DC-motor.

2. The method that will be used here is the armature-controlled DC-motor that because the most situation the field circuit of DC-motor will be fixed with permanent magnet or fix the input voltage and current.

In order to obtain the mathematical model of simple DC motor, Newton, Faraday and Kirchhoff voltage laws are used to derive the basic differential equations that govern system dynamics.

4.2 Mathematical Model of Simple DC Motor of CUC System

In this section, linear mathematical model of simple DC motor is derived. The commands come from the user to the system in the form

Fig.4.1 show the schematic diagram of the simple DC motor, its components, field circuit, armature circuit, and the applied torque on it. Also table 4.1 shows the variables and parameters of simple DC motor.

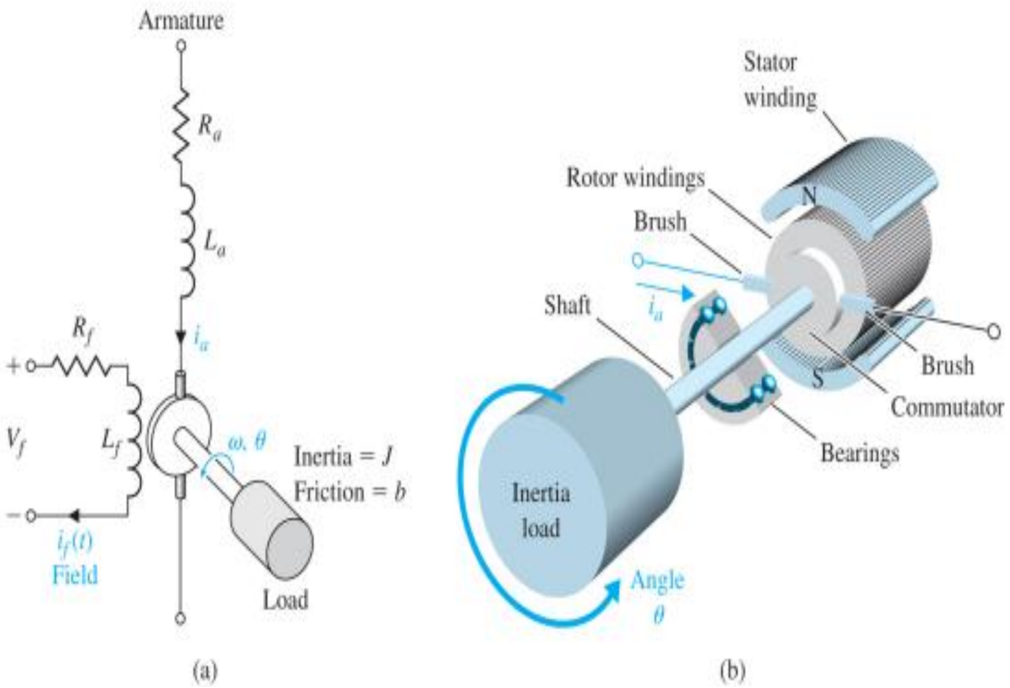

Figure 4.1 The Schematic Diagram Of Simple DC Motor

Table 4.1: variables and parameters table

Symbol	Variables and parameters	unit
ϕ	The Magnetic flux	[Wb]
k_f	The field circuit constant	[Wb/A]
I_f	The field current	[A]
T_m	The induced torque of motor	[Nm]
k_a	The armature circuit constant	[Nm/A]
I_a	The armature current	[A]
k_m	The motor constant	[Nm/A]
ϴ	The Angular position of motor shaft	[rad]
V_a	The motor armature voltage	[V]
R_a	The Armature coil resistance	[Ω]
L_a	The Armature coil inductance	[H]
V_b	The back electromotive force	[V]
ω	The angular velocity of the motor	[rad/sec]
k_b	a constant of proportionality called the back EMF constant	[voltage/(rad/sec)]
T_L	Load torque	[Nm]
T_d	Disturbance torque	[Nm]
J	Motor armature moment of inertia	[Kg.m^2]
b	friction coefficient	[Nm/radsec]
τ_m	Mechanical constant	[s]

The relation of the magnetic flux of field circuit as follow:

$$\phi(t) = k_f I_f(t)$$

So to get $\phi(t)$ constant we have to make the $I_f(t)$ constant.

The torque of motor is:

$T_m = k_a\phi(t)I_a(t) = k_a k_f I_f(t)I_a(t)$ But I_f is constant

$T_m = k_a k_f I_f I_a(t) = k_m I_a(t)$

So after that we will control the position of the motor using the voltage of armature circuit.

The transfer function of motor in s-domain is:

$$G(s) = \frac{the\ position\ of\ motor}{armature\ voltage} = \frac{\Theta(s)}{V_a}$$

$T_m(t) = k_m I_a(t)$

After taking Laplace of both sides motor torque is:

$T_m(s) = k_m I_a(s)$

By Kirchhoff voltage law

$V_a = R_a i_a(t) + L_a \frac{di_a}{dt} + V_b$

Taking Laplace for both sides equation will be

$V_a(s) = R_a I_a(s) + L_a s I_a(s) + V_b(s)$

Where $V_b = k_b\omega(s)$

Torque on load:

$T_L(s) = T_m(s) - T_d(s)$

Where T_d is disturbance often small, unknown.

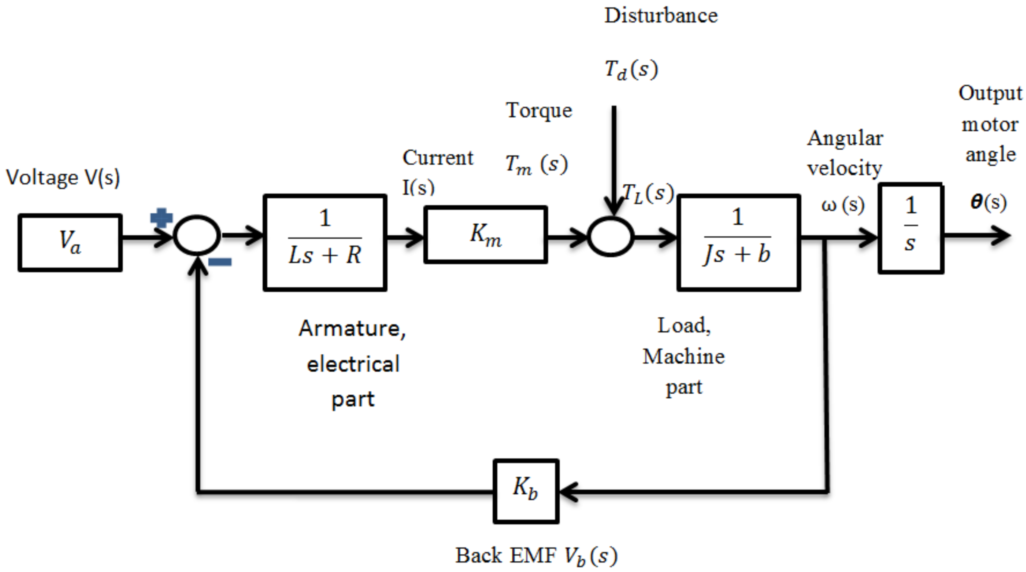

Figure 4.2 The block diagram representation of open loop simple DC motor system

We can write $T_L(s)$ in other form by using newton's law:

$$T_L(s) = Js^2\Theta(s) + bs\Theta(s) = Js\omega(s) + b\omega(s)$$

Thus $\omega(s) = \frac{T_L(s)}{Js+b}$

,and $\Theta(s) = \frac{\omega(s)}{s}$

Set $T_d(s) = 0$, then the transfer function will be like this:

$$\frac{\omega(s)}{V_a(s)} = \frac{\omega(s)}{T_m(s)}\frac{T_m(s)}{I_a(s)}\frac{I_a(s)}{V_a(s)} = \frac{1}{Js+b}k_{ma}\frac{1}{R_a + sL + \frac{k_b k_{ma}}{Js+b}}$$

$$\frac{\omega(s)}{V_a(s)} = \frac{k_{ma}}{(Js + b)(R_a + sL) + (k_b k_{ma})}$$

Then to get the transfer function of position to voltage we multiply the pervious equation with $(\frac{1}{s})$, so

$$\frac{\Theta(s)}{V_a(s)} = \frac{k_{ma}}{s[(Js + b)(R_a + sL) + (k_b k_{ma})]}$$

So the final form of equation it could be like this:

$$\frac{\Theta(s)}{V_a(s)} = \frac{(\frac{k_{ma}}{JL})}{s[(s+b/J)(s+R_a/L)+(k_b k_{ma}/JL)]}$$ (Third order system)

Sometimes the armature time constant $\tau_a = \frac{L_a}{R_a}$ is negligible, so the transfer function of motor will be:

$$\frac{\Theta(s)}{V_a(s)} = \frac{k_{ma}}{s[R_a(Js + b) + (k_b k_{ma})]}$$

So the transfer function will be like the followed form:

$$\frac{\Theta(s)}{V_a(s)} = \frac{K}{s[\tau_m s+1]} = \frac{\frac{k_{ma}}{R_a b+k_b k_{ma}}}{s[\tau_m s+1]}$$

Where:$\tau_m = RaJ/(R_a b + k_b k_{ma})$

$K = k_{ma}/(R_a b + k_b k_{ma})$

4.2.2 Mechanical constant and DC gain identification

The finding of the mechanical constant of simple DC-motor require make experiment in the laboratory, the schematic diagram of this experiment as follow:

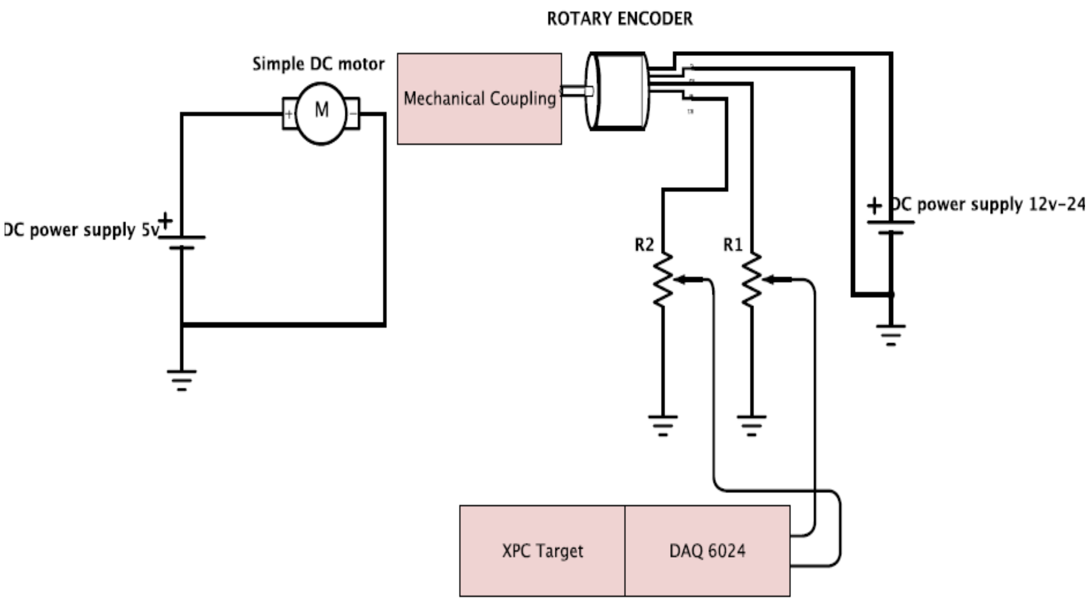

Figure 4.3 The electrical wiring diagram of finding mechanical constant experiment

XPC target model

The making of this experiment will give us the first order response of the simple DC motor to get out the mechanical constant, the response as in the figure below:

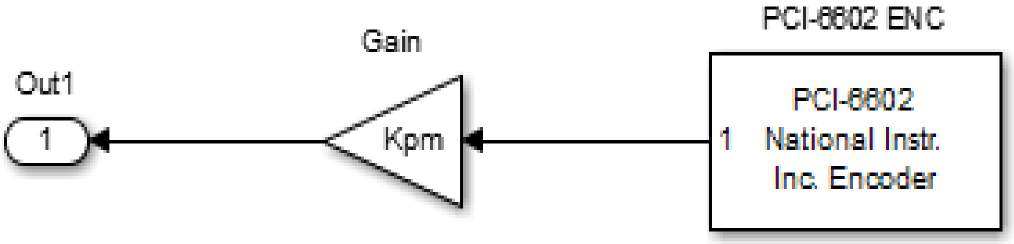

Figure 4.4 XPC-Target model

Finding the mechanical constant of the graph above will be according to the following equation:

$$y(t) = \omega(t) = 220(1 - e^{\left(-\frac{t}{T}\right)}) = 220(1 - e^{(-1)}) = 139.1(rad/s)$$

Where this value form the 63.2% of the final value.

At this point and make drop line to intersect the time axis we will get the mechanical

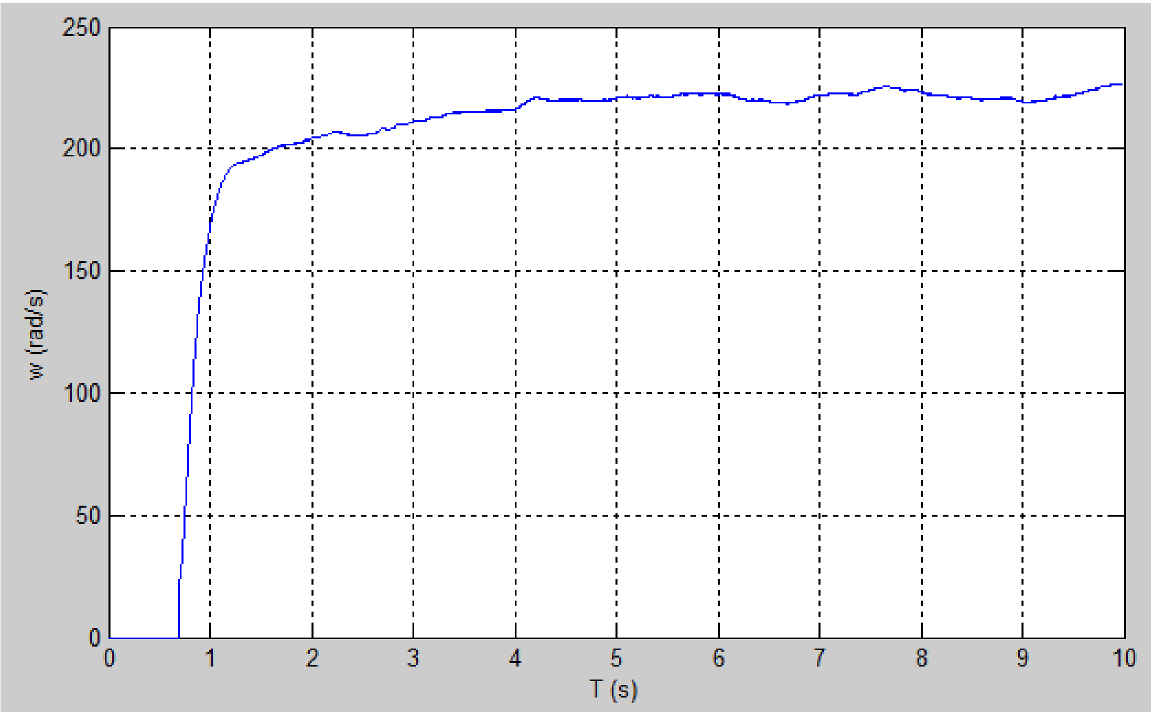

Figure 4.5 First order response of simple DC motor

time constant which equal after approximation:

$\tau_m = 0.213\ (sec.)$

So the pole of the transfer function is $\frac{1}{\tau_m} = \frac{1}{0.213} = 4.7\ Hz$

The finding of DC gain (K) of simple DC motor is as follow:

The DC gain of the system, will determine the size of steady state response when the input settles out to a constant value.

So to find the DC gain (K) of the first order response is as follow:

$$G(s) = \frac{\omega(s)}{V_a(s)} = \frac{DC\ gain}{\tau_m s + 1} = \frac{220}{0.213s + 1} = \frac{1032.86}{s + 4.7}$$

So for transfer function of

$$\frac{\Theta(s)}{V_a(s)} = \frac{1032.86}{s(s + 4.7)}$$

4.3 Gears ratio

In many applications like speed control of simple DC motor there is need to utilize the gears to change the output speed of motor to get the desired speed. This change of speed is done by using the concept of gear ratio.

Gear Ratio expresses the relationship between a Driving Gear (the gear connected to the input power source, such as a motor) and a Driven Gear (the gear connected to the output, such as a wheel or mechanism) in a system.

Gear Ratio change is one of the easiest ways to change Mechanical Advantage in a mechanism or system to achieve desired speed and/or torque.

When we have a system with a Driving Gear that is SMALLER than the Driven Gear you will increase Torque and decrease Speed:

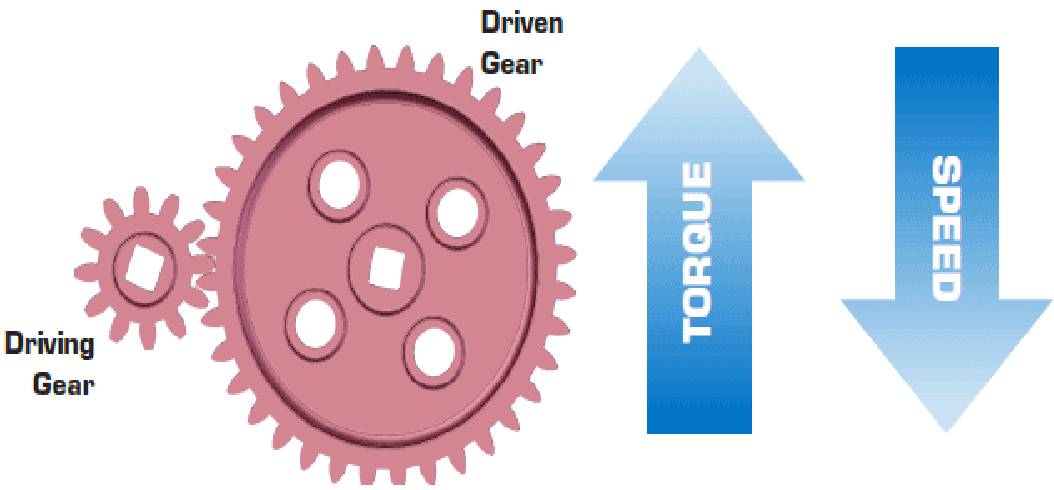

Figure 4.6 Gears Ratio effect for Driving gear small than Driven Gear

Gears Ratio has many formulas to calculate it and one of these formulas used here in this project is the ratio of the output speed to the input speed and the values of these speed is experimentally measured:

The motor “driver” speed is 220 rad/sec.

The output “driven” speed is 0.17 rad/sec

So the Gear ratio (n) is

G.R. (n) = (Driven speed/Driver speed) = $\frac{0.17}{220} = 7.7 * 10^{-4}$

So the block diagram of simple DC motor model is as follow:

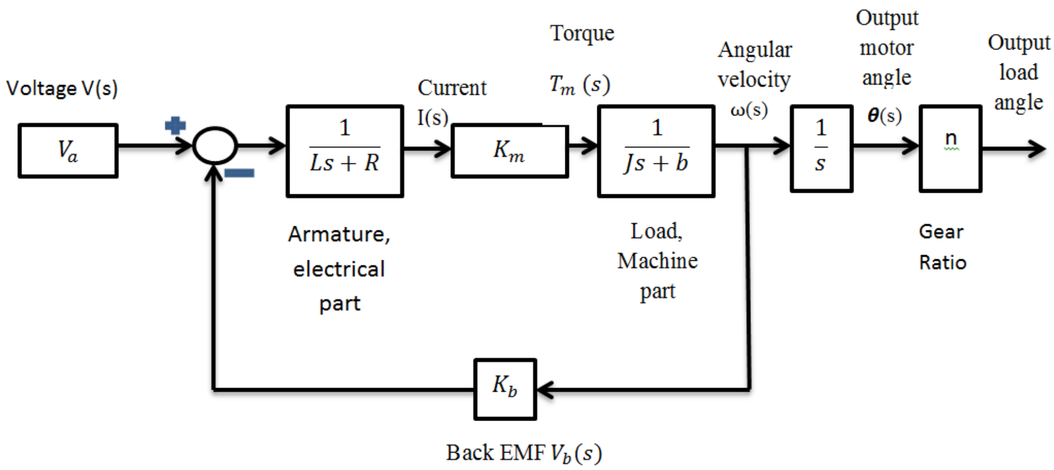

Figure 4.7 The block diagram representation of open loop simple DC motor system after adding gear ratio

So after adding Gear ratio to the model the transfer function will be as follow:

$$\frac{\Theta(s)}{V_a(s)} = n\frac{1032.86}{s(s+4.7)} = (7.7 * 10^{-4})\frac{1032.86}{s(s+4.7)} = \frac{0.8}{s(s+4.7)}$$

Chapter Five

Control System Design

5.1 Control Architecture

The understanding of the control architecture of the system is very important since it helps in designing the control system of the underwater camera. Otherwise without understanding the control architecture then it will be very difficult to design a control system that can achieve the desired task of the system which is control the orientation of the camera.

Fig. 5.1 shows the control architecture of underwater camera. In this camera the user gives the controller of underwater camera which will be the Arduino Uno signals from push button to drive DC motor to rotate the camera until reach the desired angle, means by that we have two push buttons one of them is to increase the angle of the rotation, the other is used to decrease the angle, the readout of the angle will be on the LCD that will be used to explore the angle value, after putting the desired angle and by give the motor signal to rotate the will rotate to the desired angle value and the controller of this rotation will by PID controller.

To know that the motor is on desired position we the controller system is used feedback controller utilize with the PID controller, the sensor used in the feedback is photo interrupter.

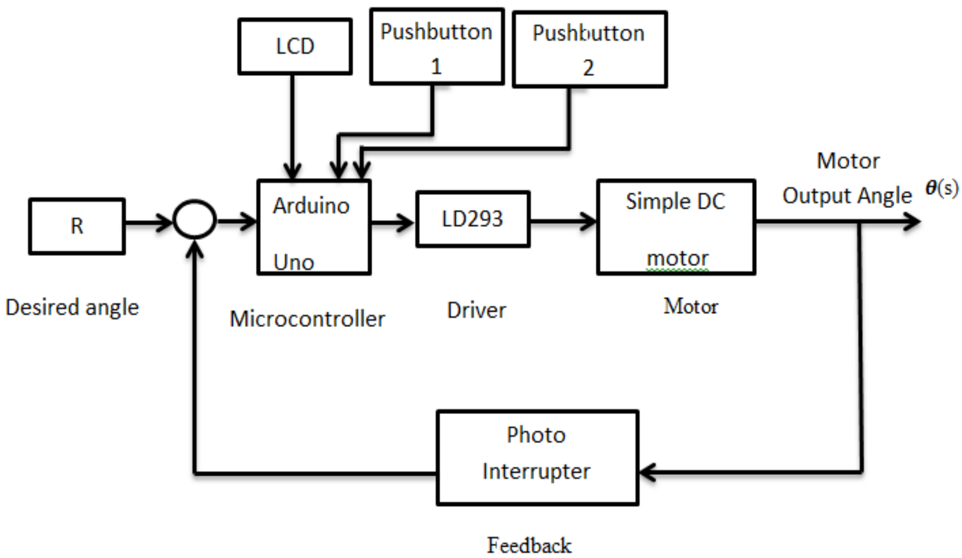

Figure 5.1: The block diagram for the control architecture of underwater camera.

5.2 PID Controller for Underwater Camera

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the integral and derivative values, denoted P, I, and D. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element.

In the Fig. 5.2 below the PID controller structure:

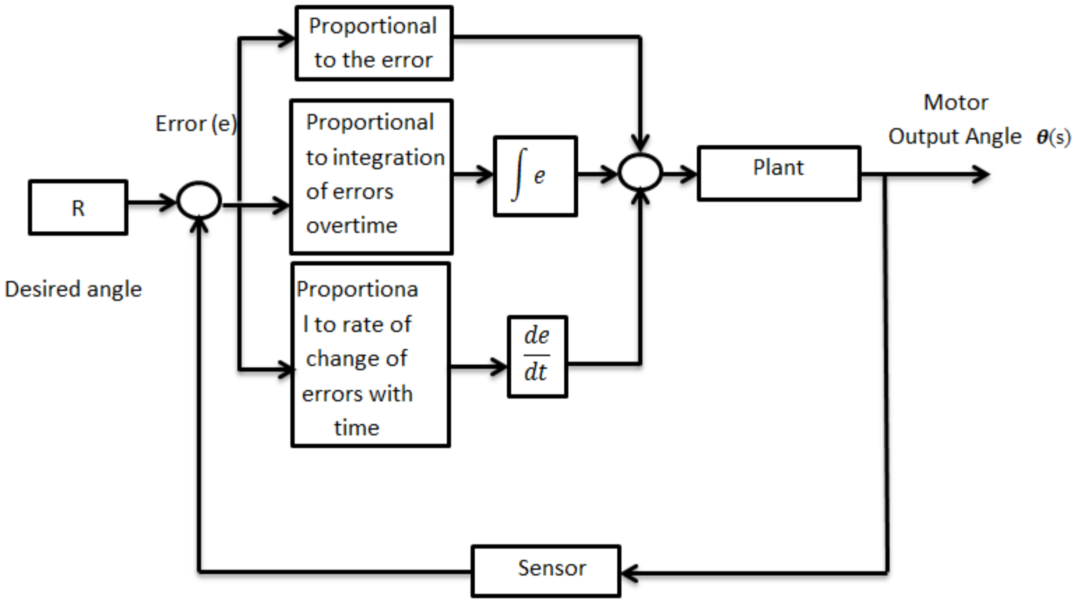

Figure 5.2: The Block Diagram for PID Controller with the System.

Chapter Six

Troubleshooting and System Integration

6.1 Troubleshooting

6.2 System Integration

6.1 Troubleshooting

In any mechatronics system troubleshooting is very important, because the problems occur in any system, and these problems affect the function of the system.

There are many electrical and electronics components in CUC system, some of these components are: 1) Microcontrollers, 2) Temperature sensor, 3) H-bridge, and 4) Push buttons.

6.1.1 The two microcontrollers used in CUC system is Arduino Uno as mentioned in section 3.1.1, the company that manufacture the Arduino Uno PCB kit put a small LED in it as shown in Fig.6.1, to make sure that the kit is work done and has no problems in computer definition, cable, or the Atmega 328P microcontroller.

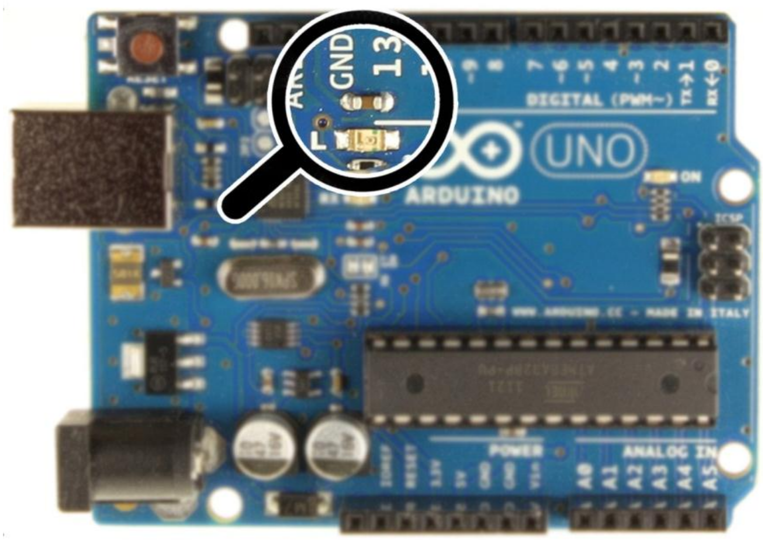

Figure 6.1 LED in Arduino Uno to the Right of L letter in the Magnifiger

1. First step: for the first plug in the computer define the kit, and the Arduino IDE program must be installed, and the computer give the kit unique port number called com number the user plug USB cable in the computer and in the Arduino Uno kit. Open computer device manger, ports the unique port number will be seen if the Arduino is defined in correct way, and there is no problem in the cable, also the type of kit will be seen beside the port number.

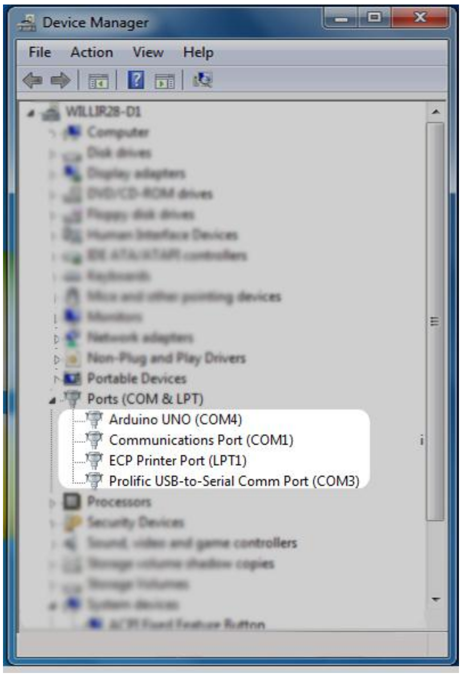

Figure 6.2 Arduino Uno on COM 4 in Device manager

Figure 6.3 Arduino Uno Cable

2. Second Step: Open Arduino IDE program, file, examples, basics, blink, the blink code will be seen in Arduino IDE program, make sure that the port number is the same for the interested kit, from Tools, Serial Ports then chose the interested port number, and make sure that the Arduino Uno chosen, from Tools, Board, Arduino Uno.

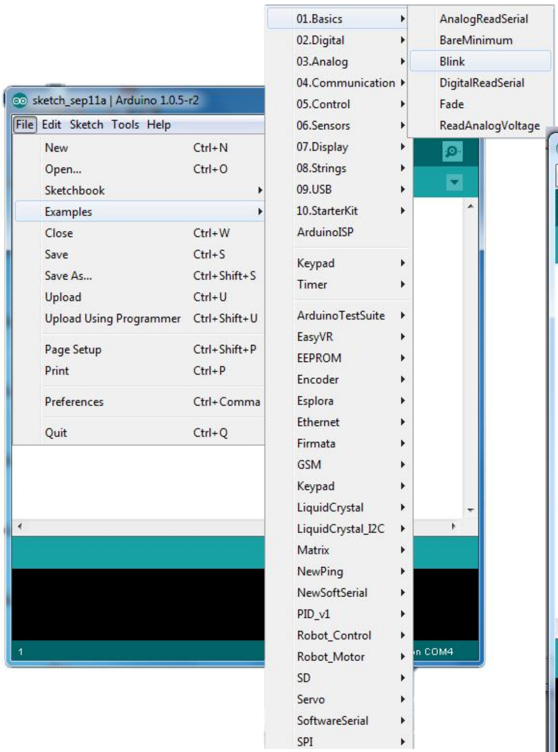

Figure 6.4 Blink code in Arduino IDE Examples

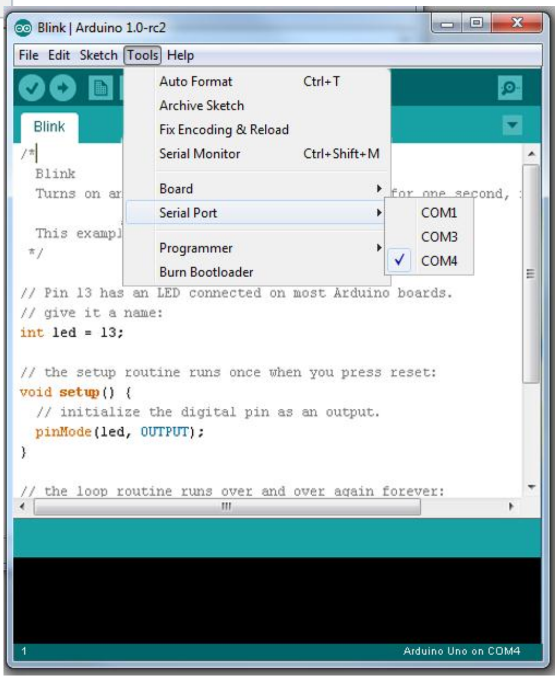

Figure 6.5 Port Number (Serial Port) chose in Arduino IDE

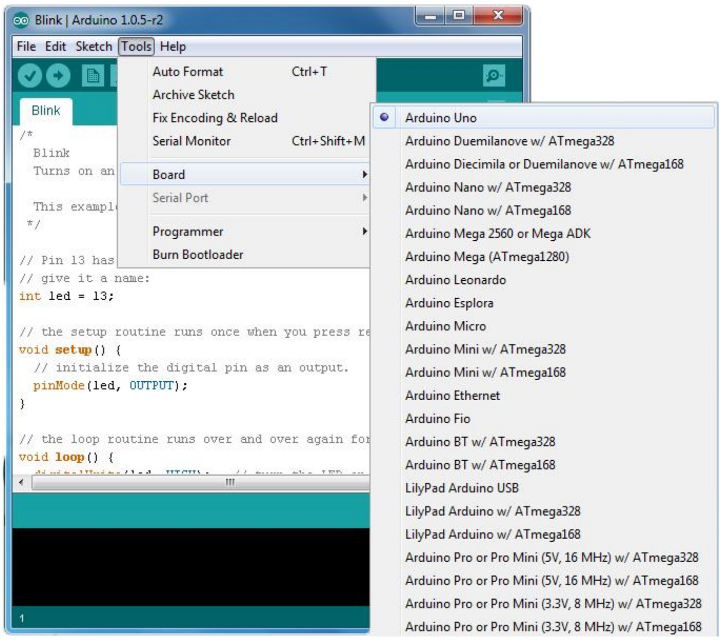

Figure 6.6 Arduino Uno selection from Boards of Arduino in Arduino IDE

3. Third Step: after these steps upload the Blink code and if there is any program in the cable and the kit the LED will blink(On then Off) continuously until the USB cable unplugged, or if another program uploaded to it, or the LED itself is burned, so an external LED with external resistor could connected to troubleshooting the kit.

6.1.2 Temperature sensor used in CUC system is lm35, it gives +10 mV / ^{o}C, in the sunny day but not hot the temperature will be between 20-28 ^{o}C, so if we put this sensor in the air the output voltage will be between 200-280 mV, after checking the electrical connection, if the output voltage entered into the Arduino Uno kit, by making calculation to convert the millivolt to Celsius, it's concluded that the equation of conversion is equal to

$$\text{millivolt} = \frac{1023 \;\; DAC\ reading\ in\ arduino}{5000}$$

```
float temp;
float millivolts;
float celsius;
int tempPin=0;

void setup ()
{
  Serial.begin(2400);
}

void loop ()
{
  // Calculating the degree in celsius
   temp=analogRead(tempPin);
  millivolts=(temp/1023.0)*5000.0;
   celsius=millivolts/10.0;

 // print the degree in celsius in Serial Monitor
  Serial.print("Temperature = ");
  Serial.println(celsius);

  delay(1000);
}
```

Figure 6.7 Temperature Code for Test and Troubleshooting Temperature Sensor.

$$Degree(\,^{\circ}C) = \frac{\text{millivolt}}{10}.$$

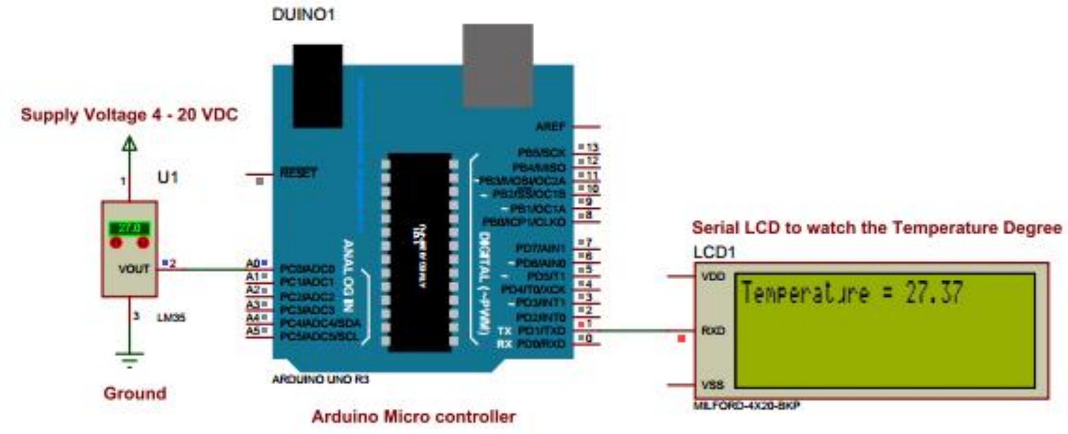

Figure 6.8 Temperature Sensor Connection with Arduino

In Fig.6.8 the serial LCD exist, because the serial monitor does not exist in the proteus simulation.

6.1.3 H-bridge used in CUC system is L293D**,** after check the electrical connection as shown in Fig. 6.9, connect the H-bridge with Arduino Uno, and

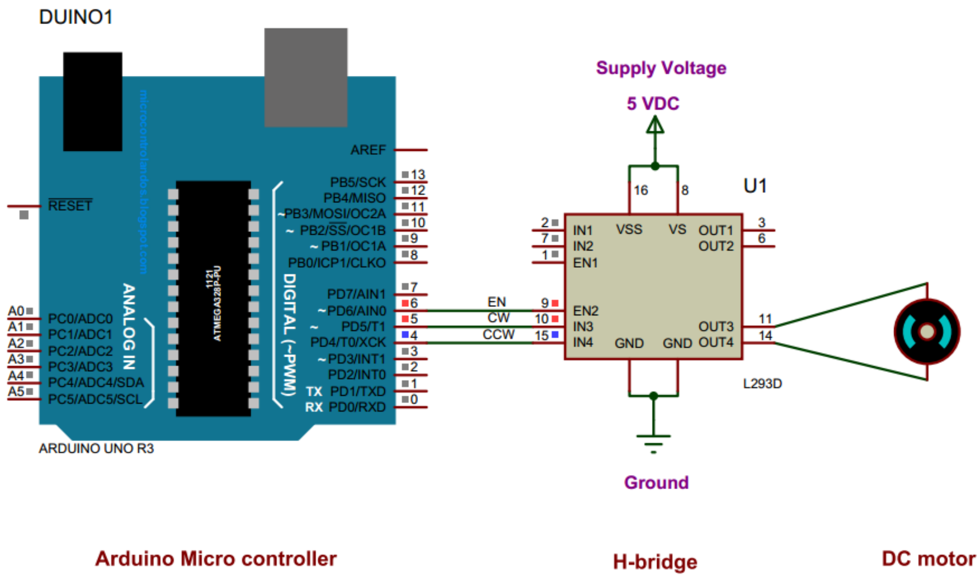

Figure 6.9 H bridge Electrical Connection.

upload the code shown in Fig.6.10 to troubleshoot the H-bridge, and make sure that it is work correctly.

```
const int EN=6;// Define the pin numbers and there names
const int CW=5;
const int CCW=4;

void setup()
{
  pinMode(EN,OUTPUT);
  pinMode(CW,OUTPUT);
  pinMode(CCW,OUTPUT);
  digitalWrite(EN,HIGH);
  // Enable the Enable pin (pin number 6)
  // Motor need enable pin to be HIGH or voltage greater than threshold
  //  to it, and one of the derection ( IN4 or IN3 in H-bridge )
}

void loop()
{
 digitalWrite(CW,HIGH);
 digitalWrite(CCW,LOW);
 // Turn on CW pin
 // Motor rotate in CW or CCW Direction (1'st Direction)
 delay(3000);  // making delay to watch the motor rotation

 digitalWrite(CW,LOW);
 digitalWrite(CCW,LOW);
 // Turn off CW pin
 // Motor Stops
 delay(200);  // make delay to protect the microcontroller
 digitalWrite(CW,LOW);
 digitalWrite(CCW,HIGH);
 // Turn on CCW pin
 // Motor rotate in CW or CCW direction (2'nd Direction reverse
 //                                        to the 1'st Direction)
 delay(3000);  // making delay to watch the motor rotation
 digitalWrite(CW,LOW);
 digitalWrite(CCW,LOW);
 // Turn off CCW pin
 // Motor Stops
 delay(200); // make delay to protect the microcontroller

}
```

Figure 6.10 H-Bridge Code for Testing and Troubleshooting, and Make Sure It Is Work Correctly

6.1.4 Push buttons is used in CUC system to change the degree, confirm it, and turn on and off the LED lighting.

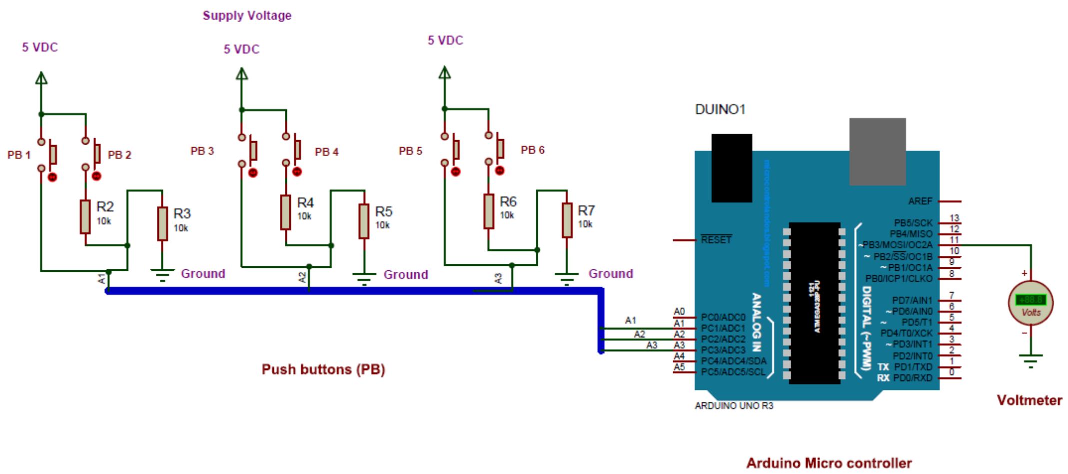

Figure 6.11 Push Buttons Electrical Connection.

```
void setup()
{
}

void loop()
{
   // Test analog pin number 1 +
    if(analogRead(1)>950)
           analogWrite(11,25);//Output voltage for pin 11 = 0.5
   // Test analog pin number 1 -
    else if(analogRead(1)>400 && analogRead(1) <600 )
           analogWrite(11,50);//Output voltage for pin 11 = 1

    //  Test  analog  pin  number  2
    if(analogRead(2)>950)
           analogWrite(11,100);//Output voltage for pin 11 = 2
    // Test analog pin number 2
    else if(analogRead(2)>400 && analogRead(2) <600 )
           analogWrite(11,150);//Output voltage for pin 11 = 3
    //  Test  analog  pin  number  3
    if(analogRead(3)>950)
              analogWrite(11,200);//Output voltage for pin 11 = 4
    //  Test  analog  pin  number  3
     else if(analogRead(3)>400 && analogRead(3) <600 )
                analogWrite(11,255);//Output voltage for pin 11 = 5

   delay(1000);


}
```

Figure 6.12 Push Bottons Arduino Code For Testing And Troubleshooting.

After check the electrical connection upload the test code shown in Fig.6.12, and measure the output voltage from pin number eleven(11) to toubleshoot the push button.

6.2 System Integration

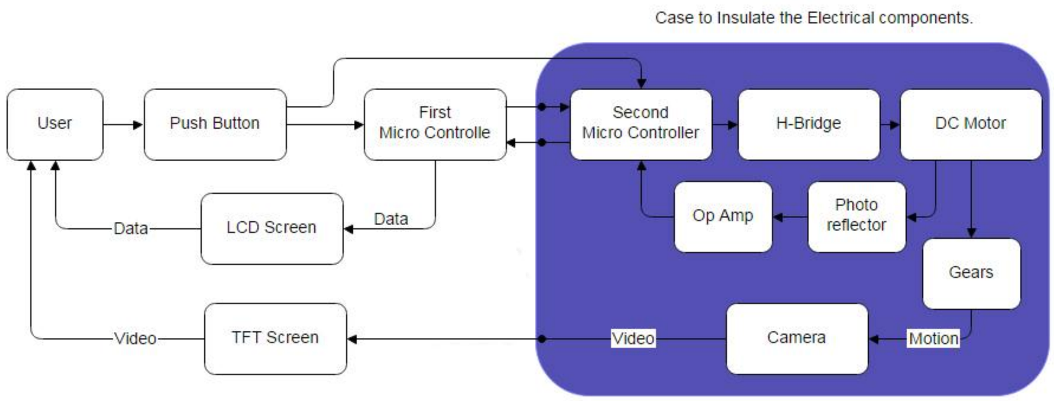

Figure 6.13 Hole System Integration

The system integration shown in Fig.6.13, the user is commander and the input controller for the system, the user press the push buttons to increase and decrease the desired angle, the first microcontroller shows the desired angle on the LCD screen, so the user can see it, and when the user reach the desired angle he or she confirms or cancels the desired angle, if the angle is confirmed the first microcontroller send the desired angle to the second microcontroller, the second microcontroller receive the desired angle and compares it with the measured so it make decision for movement depend on the measured and desired angle, and starts to calculate the error and makes output voltage to the H-Bridge to move the motor clockwise or counterclockwise, when the gears rotates the photo reflector reading change depend on black stick tip on the second gear, this reading filtered by operational amplifier, and the reading of the output filtered signal entered to the interrupter pins 2 and 3, and this make the counter increase depend on the direction of movement, and this operation still in loop until the measured angle equals the desired angle.

In this time of loop the second microcontroller send the temperature and the measured angle to the first microcontroller, when the first microcontroller receive the data from the second one the data, the first micro controller analyses the data, and show them on the LCD.

In every second the video camera send the video to the TFT screen and the user watches the data on it.

All these steps in closed loop, to make sure that the system running for long time, and does not stop in view minutes.

Chapter Seven

Conclusion and Future Work

7.1 Introduction:

This chapter provides the conclusion of the whole device as a complete system. In addition, the future works are found here.

7.2 Conclusion:

The device is proved-by doing an experiment-to be suitable for searching, view underwater places on 40 meter underwater depth.

7.3 Future Work:

It is recommended to investigate the following in future works:

1) Fail Safe property to protect the system from damaging itself.
2) Self Diagnoses property to give the user information about the error and fault that maybe happen in the system.

Appendix A

```
//First Microcontroller Programming

#include<LiquidCrystal.h>


LiquidCrystal lcd( 2, 3, 4, 5, 6, 7 );

//LiquidCrystal lcd( RS , E , D4, D5, D6, D7)



boolean plus=false;

boolean minus=false;

boolean confirm=false;

boolean cancel=false;

//plus, minus,confirm, and cancel equal true if the desired push button is pressed


int des_th=0; // To store the value of Desired Theta in it( Desired Angle)

int mes_th=180; // To store the value of Measured Theta in it( Measured Angle)

float temp=0; // To store the value of Temperature in it

int des_th_p=0; // To store the value of Previous Desired Theta in it

        //= des_th + - 1; because the programm add or sustract 1 if the plus or minus is
True
```

```
}

int i=0; // i increase 1 every microcontroller loop
int ii=0;// ii increase 1 every microcontroller loop
int iii=0;


int confirm_int=1;
int send_confirm=1;
int x=0; // used to store and send the Desired Theta in it.

char ch =0; // use to read the recieved character
unsigned long value=0; // used in storage the data until the next data recieved
unsigned long value_1=0; //  used in recieving data

void setup()
{

 Serial.begin (2400);
 lcd.begin(16, 2); // define the number of rows and columns in LCD
 lcd.clear(); // command to clear every thing on LCD
 //lcd.clear();
 print_names();
}
```

```
void loop ()

{


 if( Serial.available())

  {


    char ch = Serial.read();

    if( isDigit(ch) )// is this an ascii digit between 0 and 9?

    {

      value_1 = (value_1 * 10) + (ch - '0'); // yes, accumulate the value

    }

    else if (ch == 10)  // is the character the newline character?

    {

     // Serial.println(value_1);

      value=value_1;

      value_1 = 0; // reset val to 0 ready for the next sequence of digits


    }

  }



       switch (i)

         {
```

```
            case 1:
             break;

            case 10000:
             i=0;
             if(send_confirm==2)
             {
               x=(des_th+180) ;
               Serial.println(x);//send_Desired_theta ;
             }
            break;
```

// i= 0 to 10000 to make delay in sending the Desired Angle without make delay in the procces it self

```
            default:
              break;
          }
            i++;


switch (ii)
 {
```

```
case 5000:
  if(confirm_int==1)
  {
      lcd.setCursor(11,1);
      lcd.print(mes_th);
      lcd.print((char)223);
      lcd.print("    ");
  }

  if( plus==false && minus==false && confirm==false && cancel==false  &&
confirm_int==1 )
  {
    lcd.setCursor(0,0);

    lcd.print("Desired  ");
    lcd.print((char)242);
    lcd.print("=");
    lcd.print(des_th);
    lcd.print((char)223);
  }

break;

case 10000:
   if( confirm_int==1)
```

```
  {
   lcd.setCursor(0,1);
   lcd.print("Measered ");
   lcd.print((char)242);
   lcd.print("=");
   //Calulate the Temperature from the recived value

    mes_th=(value-value%1000000)/1000000;
    mes_th=mes_th%1000;
    mes_th=mes_th-180;
    lcd.print(mes_th);
    lcd.print((char)223);
    lcd.print("    ");
  }

 break;


case 15000:
 if(confirm_int==1)
  {
    lcd.setCursor(11,1);
    lcd.print(mes_th);
    lcd.print((char)223);
```

```
    lcd.print("    ");
   }

   temp=value%1000;
   temp=temp/10; //Calulate the Temperature from the recived value

  if( plus==false && minus==false && confirm==false && cancel==false  &&
confirm_int==1 )
    {

    lcd.setCursor(0,0);
    lcd.print("Temp= ");
    lcd.print(temp);
    lcd.print((char)223);
    lcd.print("C");
    lcd.print("   ");
    }
   break;

 case 20000:
  ii=0;
  // ii= 0 to 10000 to make delay in sending the Desired Angle without make delay in the
procces it self
 break;
```

```
  default:
    break;
}
ii++;


 if(analogRead(0)>=900 && confirm_int==1 && des_th<=180 ) // deg ++
    {

      lcd.setCursor(0,0);
      lcd.print("Desired  ");
      lcd.print((char)242);
      lcd.print("=");
      lcd.print(des_th);
      lcd.print((char)223);
      lcd.print("    ");
      plus=!plus;
      minus=false;
      delay(1000);

    }


  else if(analogRead(0)>=400 && analogRead(0)<=650 && confirm_int==1 &&
abs(des_th)<=180 ) // deg --
```

```
{
  lcd.setCursor(0,0);
  lcd.print("Desired  ");
  lcd.print((char)242);
  lcd.print("=");
  lcd.print(des_th);
  lcd.print((char)223);
  lcd.print("    ");
  minus=!minus;
  plus=false;
  delay(1000);
 }



 if( plus==true && des_th<=180  )
  {
    if(  (  (abs(des_th)%100)==0 && (abs(des_th_p))==101 )  || ( ((abs(des_th%10))==0
&& (abs(des_th_p))==11) ) || (des_th==0 && des_th_p==-1) )
     {
      lcd.setCursor(11,0);
      lcd.print("      ");
     }
```

```
des_th++;

lcd.setCursor(11,0);

lcd.print(des_th);

lcd.print((char)223);

delay(200);

}

else if(minus==true && abs(des_th)<=180)

    {

      if(  (  (abs(des_th)%100)==0 && (abs(des_th_p))==101 )  || (
((abs(des_th%10))==0 && (abs(des_th_p))==11) ) )

       {

        lcd.setCursor(11,0);

        lcd.print("      ");

       }


     des_th--;

     lcd.setCursor(11,0);

     lcd.print(des_th);

     lcd.print((char)223);

     delay(200);

    }



if(((abs(des_th)%100)==0 && abs(des_th_p)==101 )  || ((abs(des_th%10))==0 &&
abs(des_th_p)==11) )
```

```
 {
  lcd.setCursor(11,0);
  lcd.print("    ");
 }


if(abs(des_th)>=181)
  {
    if(plus==true)
      {
        plus=false;
        des_th=180;
        lcd.setCursor(11,0);
        lcd.print(des_th);

      }

     if(minus==true)
      {
        minus=false;
        des_th=-180;

        lcd.setCursor(11,0);
        lcd.print(des_th);
```

```
            }

        }

if(analogRead(1)>=900) // confirm
   {
     confirm=true;
     minus=false;
     plus=false;
   }
 else if((analogRead(1)>=440) && (analogRead(1)<=650))
    {
      cancel=true;
      minus=false;
      plus=false;
    }

 if( confirm==true && confirm_int==1 )
  {
     lcd.clear();
     lcd.setCursor(0,0);
     lcd.print("Des");
     lcd.print((char)242);
```

```
  lcd.print("=");
  lcd.print(des_th);
  lcd.print((char)223);
  lcd.setCursor(9,0);
  lcd.print("Confirm");
  lcd.setCursor(6,1);
  lcd.print("or Cancel");

  confirm_int=3;
  delay(2000);
  confirm=false;
}

 if(confirm==true && confirm_int>=2 )
 {
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print((char)242);
  lcd.print(" Confirmed");
  lcd.setCursor(0,1);
  lcd.print((char)242);
  lcd.print(" = ");
  lcd.print(des_th);
  lcd.print((char)223);
```

```
  delay(3000);
  confirm_int=1;
  confirm=false;
  lcd.clear();
  send_confirm=2;
  i=1000;
  ii=10000;
}


 if(cancel==true )
{
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print((char)242);
  lcd.print(" Canceled ");
  delay(3000);
  confirm_int=1;
  confirm=false;
  cancel=false;
  lcd.clear();
  send_confirm=1;
}
```

```
    des_th_p=des_th;

}

void print_names()
{
  lcd.setCursor(0,0);
 lcd.print("Graduating ");
 lcd.setCursor(0,1);
 lcd.print("Project");
 delay(2000);
 lcd.clear();
 lcd.setCursor(0,1);
 lcd.print("Controlling ");
 delay(2000);
 lcd.setCursor(0,0);
 lcd.print( "Controlling ");
 lcd.setCursor(0,1);
 lcd.print("UnderWater ");
 delay(2000);
 lcd.setCursor(0,0);
 lcd.print("UnderWater ");
 lcd.setCursor(0,1);
```

```
lcd.print("Camera (CUC)");
delay(2000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Camera (CUC)");
lcd.setCursor(0,1);

delay(2000);
lcd.clear();
lcd.setCursor(0,1);
lcd.print("Done By:");
delay(1000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Done By:");
delay(1000);
//lcd.autoscroll();

lcd.setCursor(0,1);
lcd.print("Adam Abu Dayyeh");
delay(1000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Adam Abu Dayyeh");
```

```
 lcd.setCursor(0,1);
 lcd.print("Abdallah ND");
 delay(5000);
 lcd.clear();
 lcd.setCursor(0,1);
 lcd.print("Supervisor:");
 delay(500);
 lcd.setCursor(0,0);
 lcd.print("Supervisor: Eng.");
 lcd.setCursor(0,1);
 lcd.print("Majdi Zalloum");
 delay(5000);
 //Serial.print("0");
 lcd.setCursor(0,0);
 lcd.clear();
 delay(1000);
}
```

Appendix B

```
//Sender code
 #include <TimerOne.h>


 const int CCWdir=4;

 const int CWdir=5;

 const int  OUT=6;

 double u,r,e,ep,epp,Ip,up,upp,c;


 //u Input for motor

 //e Error

 //c Feedback

 //r input desired angle


 int count=3.467;


 float y=0;

 float Ts=0.01;




 double Kp=120;
```

```
double Ki=0.0;
double Kd=0.0;


double A=(Kp+((Ki*Ts)/2)+((2*Kd)/Ts));
double B=((Ki*Ts)-((4*Kd)/Ts));
double C=(-Kp+(Ki*Ts)/2+(2*Kd)/Ts);
double D=1;
float Kpm=1/3.467;


float temp=0;
float millivolts=0;
float celsius=0;

int tempPin=0;
int des_degree=1;
int m_degree=1;

const int LED=3;
boolean LED_ON_OFF=false;

int i=0;
```

```
unsigned long x=0;       // Packaging the Temp and Measured deg to send it.

unsigned long value=180;    // To put the receiving value in it

unsigned long value_1=180;  // To put the receiving value in it


void setup()

{


  u=0;

  e=0;

  c=180;

  r=180;//******************************************************** Refrence

  ep=0;

  epp=0;

  up=0;

  upp=0;

 pinMode(CCWdir,OUTPUT);

 pinMode(CWdir,OUTPUT);

 pinMode(OUT,OUTPUT);

 pinMode(LED,OUTPUT);


//   Timer1.initialize(10000); // set a timer of length 100000 microseconds (or 0.1 sec - or 10Hz => the led will blink 5 times, 5 cycles of on-and-off, per second)

//   Timer1.attachInterrupt( timerIsr ); // attach the service routine here

 //attachInterrupt(0, Count, RISING);

 // attachInterrupt(1, Count1, RISING);
```

```
 Serial.begin(2400);
}

void loop()
{
  temp=analogRead(tempPin);
  millivolts=(temp/1023.0)*5000.0;
  celsius=millivolts/10.0; // reading the Temperature in the Mechanical case

 //recieve
  if( Serial.available())
   {

    char ch = Serial.read();
    if( isDigit(ch) )// is this an ascii digit between 0 and 9?
    {
      value_1 = (value_1 * 10) + (ch - '0'); // yes, accumulate the value
    }
    else if (ch == 10)  // is the character the newline character?
    {
     //Serial.println(value_1);
      value=value_1;
      value_1 = 0; // reset val to 0 ready for the next sequence of digits
    }
```

```
}

if( analogRead(1)>=350 && analogRead(1)<=650 )
 {
     c=180;
    // Reset the counter

 }

 if( analogRead(2)>=350 && analogRead(2)<=650 )
   {

    r=c;
    digitalWrite(CWdir,LOW);
    digitalWrite(CCWdir,LOW);
    digitalWrite(OUT,LOW);
    // Cancel

   }
   else   if(value>=0 && value<=360)
           r=value;
```

```
 i++;
  switch (i)
  {
      case 50:
          m_degree=c;
          x = celsius*10+  int(c)*1000000   ;
          Serial.println( x  );


          i=0;
        break;


      case 15000:
       break;


      default:
         break;
  }



//   Serial.print("x =");
 //   Serial.println(x);
```

```
  if( (analogRead(1)>=650) )
   {

      LED_ON_OFF=!LED_ON_OFF;
      //digitalWrite(LED,LED_ON_OFF);
      if(LED_ON_OFF==true)
        analogWrite(LED,200);
      else digitalWrite(LED,LOW);

      delay(3000);


      // LED On or OFF
   }


// ************************* PID ****************************************

if(u>255)
 u=255;
 else if(u<0)
  u=10;
```

```
if(abs((r-c))<1)
    c=r;

 delay(100);
   if((r-c)==0)
  {

    digitalWrite(CCWdir,LOW);
    digitalWrite(CWdir,LOW);

  }
  else
  if((r-c)<0)
   {
    digitalWrite(CCWdir,HIGH);
    digitalWrite(CWdir,LOW);
    c=move_cw(c);
   }
   else
   if((r-c)>0)
  {
   digitalWrite(CCWdir,LOW);
   digitalWrite(CWdir,HIGH);
   c=move_ccw(c);
```

```
    }

  //delay(200);

 }

 void timerIsr()
 {
  //c =count/3.4;

//   e=r-c;
//
//   u=A*e+B*ep+C*epp+D*upp;
//
//   epp=ep;
//   ep=e;
//   upp=up;
//   up=u;
```

```
}



void Count()
{
//  count--;
}

void Count1()
{
  //count++;
}



double move_cw( double c)
{
  digitalWrite(OUT,HIGH);
  delay(100);
  digitalWrite(OUT,LOW);
  c=c-.9;
  return c;
}
```

```
double move_ccw( double c)
{
  digitalWrite(OUT,HIGH);
  delay(100);
  digitalWrite(OUT,LOW);
  c=c+0.9;
  return c;

}
```

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