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Smart & Mobile Solar Powered Fish Farming Unit

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Chapter 1

Survey on Fish-farming and Aquaculture.

1.1 Introduction.

Fish farming is part of a broader and more comprehensive term: **aquaculture**, which is breeding certain species of marine life fish, crustaceans, shellfish, marine algae, etc., **under controlled conditions**

of feeding, growth, hatching, harvesting, water quality and appropriate environmental conditions **under human control**. Thus, **PISCI-Culture** can be defined as the raising of fish of all kinds, **whether salt or freshwater fish,** as food for humans under controlled under conditions and human control, **and in certain areas**, whether ponds or cages. It **aims to** improve production and stabilize farm ownership of products.

Fish farming and pond farming has been known since ancient times and is known to have been **developed by old farmers** for the purpose of **stabilizing** their food resources. The **first** we know of **pond fish farming** came from **China 4,000 years ago**, and **Mesopotamia about 3,500** years ago. Pond fish farming was then **integrated with rice cultivation** from **25 to 220 AD in China.** Fish culture in **the Mediterranean basin** was known during **the Roman Empire**. It later became one of the means of **food production in Christian monasteries** in **Central Europe**. **At present**, aquaculture extends beyond fish farming in ponds or rice fields. **The FAO** now defines aquaculture as growing **not only fish,** but also crustaceans, shellfish and aquatic plants.

1.2 The importance of fish farming.

Fish farming now offers many benefits as a means of:

1. Developing **a rich food for human consumption.**
2. Increasing **income in rural areas** and reducing **unemployment**.
3. **Earning income** by farming and **selling** fish.
4. Breeding special varieties of species for **decoration purposes.**
5. Controlling water **weeds and insects** harmful to humans or to the crops.
6. Removing salts, reforming and re-fertilizing **the soil**.
7. Achieving **the principle of biological resistance to diseases**.
8. Controlling the growth and reproduction of fish in terms of **quantity and quality.**

In the future, **aquaculture** will have a great contribution as a food for humans. **The increasing population** of the world has increased the demand for fish to the extent that **the available of several species is falling and no longer meet the growing needs.** On the other hand, the communities in most need of **introducing more fish and fish products** in their food are unable to do so because **prices exceed their purchasing power.**

1.3 The pillars of aquaculture.

Aquaculture stands on two main pillars: **water and location**. First, we will talk about water as a pillar of aquaculture and a source of life for fish.

1.3.1 Water.

Water is considered one of the basic elements in the process of **aquaculture** provided that the following conditions are met:

1. Available permanently and without interruption.
2. Contaminant-free.
3. Free of pathogens.

4. Low cost.

Its sources are either seawater, rivers, well water or treated wastewater. **Well water** is the most important source of water for aquaculture operations, as **farms established in agricultural lands** depend on it. This system utilizes water in an **open system** where the water **is pumped to the fish ponds** first and then **to farm production plant.** When drilling the well, it should be considered that the well is deep enough to pump water free of contaminants. Analyze a sample of the well's water to determine its suitability and ensure its **quality** and **free of toxic compounds** before being used in fish farming.

1.3.2 Characteristics of aquaculture water.

In a brief manner the recommended **general characteristics** of aquaculture water are as follows:

- Recommended **concentration of some elements** in aquaculture water (mg / l):
  - **Oxygen** gas: 5 or more.
  - **Ammonia** gas: 0.05.
  - **Carbon dioxide** gas: 10 or less.
  - **Mercury**: zero.
- PH (ph):

  The pH expresses the properties of the acidic or alkaline aqueous medium. Each fish has an optimal pH and generally all fish species prefer a **low alkaline water** medium of **7.5 to 8.**

On the other hand, those previous specifications can not provide a complete description of the water needed for aquaculture. Instead, the characteristics of water required in fish farms can be divided into two parts:

1.3.2.1 Natural characteristics.

The Natural characteristics include:

1- Light and turbidity

Turbidity is a measure of the amount of **substances suspended in water**, which may result from various reasons. It may be caused by **rain and floods**, carrying **molecules of mineral elements**. It may also result from **the activity of fish in the breeding seasons,** where fish chasing each other, or as a result of **competition for prey.** This may **stir the bottom contents** and **turbid the water.** This **hinders the light** to reach the **phytoplankton** microorganisms**, reducing** the **oxygen levels** required for **photosynthesis** of those microorganisms. This affects the **growth rate** of fish and may result in the spread of **fungal diseases.**

It is known that the light falling on the surface of the water does not **refract** as a whole, but part of it is **reflected**. The amount reflected depends on **the angle of the fall**, and the **nature of the surface of the water**. The type of light changes and the **intensity decreases** as it passes through the water, due to **the dispersion** caused by, most notably **water-suspended substances**.

<u>Turbidity level:</u>

Turbidity, as mentioned above, reduces the penetration of light, and therefore **the rate of photosynthesis and plankton production** is reduced, which makes it difficult for fish to obtain food, and this factor pushes them to predation process, as it has a mechanical effect causing **gill wound.** It should be noted that **the degree The concentration of turbidity required in ponds with clay soils is about 200 ppm.**

2- Water Color:

1. **Green** indicates **increased** phytoplankton and other types of algae.
2. The **bluish** color of blue indicates **some species of algae**.
3. **Brown** indicates **increased** humus content.
4. The **greenish brown** color indicates the **mixture of humus and phytoplankton.**

3- Water temperature:

Fish growth rates at optimum temperatures are highest, but if fish are at a lower or a higher temperature they do not grow normally. Heat plays an important role in fish's vital processes such as **metabolism, reproduction and especially spawning**. Fish should live in a certain range of temperatures, depending on their species and the stages of growth in which they are found.

Depending on their tolerance to water temperature, fish are divided into:

- cold-water fish, which mate at 15 ° C or less,
- and warm-water fish mate at temperatures above 16 ° C.

For example, **tilapia fish** need to live in a range of temperatures ranging **from 22 to 25 degrees Celsius**, **stop feeding if the temperature drops to 16 degrees** Celsius, and **at 10 degrees** Celsius become vulnerable to **death**, while tilapia **hatcheries** need **between 28 - 30 degrees Celsius.**

The high temperature stimulates the **solubility of chemicals** in water, which **negatively** affects the vitality of fish. On the other hand, the rate of **dissolution** of **oxygen** in water increases with temperature. The following table shows the suitable temperature ranges for several types of tilapia:

	Temperature at which fish begin to die (° C)	Temperature at which fish begin to be affected (° C)	Temperature at which fish start growing (° C)	Temperature at which fish start spawning (° C)	Optimum incubation and growth temperature (° C)
O.oureus	8	13	-	21	21-29
S.galilaeus	8	13	-	-	-
S.macrohir	11	14	-	-	23-40
S.macrocepholy	9	-	-	-	26-32
O.mossambicus	13	11	15	22	26-31
O.niloticus	11	-	15	21	30-28
T.rendalli	11	-	19	-	-
T.sporrmanii	6	-	-	16	-
T.zillii	6	-	20	20	26-32

1.3.2.2 Chemical properties.

Chemical properties include:

1. **dissolved oxygen in water:**

One of the most important factors affecting aquaculture is the dissolved oxygen in the water. Some of the problems that fish are exposed to when they **lack oxygen** are:

- Sudden or gradual **death** of fish.
- Lack of **growth rates**.
- Stress and the emergence of various **diseases**.
- Fish stop eating and lose **appetite.**

The **signs** of **lack of oxygen** in water are as follows:

- **Fish gather at the surface of the water and their mouths open,** in constant movement to get oxygen from the surface of the water.
- Fish swim **slowly and randomly.**
- Fish gather **at irrigation gates** and openings that have some leakage of water.
- **Fish deaths** especially **during the night.**
- The lack of **appetite** for food.

The **causes** of **lack of oxygen** in water are:

- **Death and decomposition** of **plants** within ponds.
- The **lack of light during the day**, which leads to a **decrease** in the rate of **photosynthesis**.
- **Increased breathing** rate of fish as a result of exposure to abnormal conditions such as **excitement or high water temperature**.
- Providing ponds with **large quantities of food** that **exceeds** the **needs** of fish. Therefore part of it is **decomposed and oxidized**, which consumes a large proportion of dissolved oxygen in water.
- Increase the **density of plants and algae** in the pond above the required rate.

The **lack of oxygen** in water **is treated by**:

- **Mechanical ventilation** through **air pumps** is one of the most commonly used methods to increase the oxygenation of fish farm water with **pumice stone**. Other methods such as **switches** and water suction, use, then re-pumping in the form of **butter-like flows** are sometimes implemented**.**

- **Add oxidizing salts** to water such as **potassium permanganate.** This method is **expensive** and does not lead to a significant increase in the proportion of oxygen.
- Alert fish farm workers not to feed or transport fish in the case of lack of oxygen. This leads to the **decomposition of food in the pond and therefore more lack of oxygen.**
- **Heat** plays an important role in **the solubility of oxygen**, where the degree of solubility depends on the **temperature of water and its salinity**. The concentration of **5 mg oxygen / liter** of water is suitable for most of the fish. However, **some cold water fish** need a **higher concentration**. There are also other types of fish that can live in water where oxygen concentration is **below this level**.

It should be noted that the proportion of **saturated water flow** within the pond should be **100% oxygen**, and **not less than 80%,** and fish are **killed** if the proportion of oxygen in the water **less than 5 parts per million.**

Active fish require **higher oxygen levels** than less active fish. **Smaller fish consume more oxygen** than larger fish. Critical limits of oxygen vary depending on fish species. **Fish prefer high concentrations of oxygen at different levels.**

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2. Water Salinity:

Salinity can be defined as **the amount of salts dissolved in 1 kg or a liter of water**. Salinity is measured by special scientific devices, including (**Salinometer**), and divided fish into three sections depending on the degree of tolerance of salinity:

i- Saltwater fish:	They live in seawater, where salinity **exceeds 30 parts per thousand.**
ii- Freshwater fish:	They live in fresh water and have a salinity of **only 0.5 ppm.**
iii- Brackish water fish:	They lives in water salinity ranging from more **than 0.5 parts per thousand to less than 30 parts per thousand**.

There are species of fish that can **cope** with **the extreme change** in the salinity of water. They can live in fresh water and salt water without any negative effects on their lives. Most of these fish are considered **migratory fish from freshwater salt water or vice versa**. **Salmon fish** are an example of such fish.

In general, the salinity of water should be taken into account when establishing the farm and **choose the appropriate fish type for this salinity**.

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3. Carbon dioxide:

High carbon dioxide in water may not become a problem if there is **plenty of oxygen**. Some **catfish** may tolerate **140 ppm of carbon dioxi**de, if **10 ppm** of dissolved oxygen is available in water. This increase in gas in water causes it to **reach the brain and heart of the fish**, killing it.

It should be noted that **well water** has **less oxygen** content and **more carbon dioxide**. Therefore, it is necessary to use oxygen pumps to adjust the proportions of each in the water.

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4. Water pH:

It stands for the concentration of **the hydrogen ion** in water. Experts in the field of aquaculture say that **exceeding the hydrogen Ph amount of the range of 4.5 - 10 impedes the growth of fish**. It is known that the amount of Ph for **fresh water** is variable. For **salt water,** it is **8.1 - 8.3 in surface areas**, and reduced to **7.5 In depths**. In ponds containing **hydrogen sulfide gas,** this value drops to **0.7**.

pH indicators are known to be affected by the presence of **aquatic plants** consuming carbon dioxide and by the **pH of the soil itself**, which can be overcome **by adding lime**.

Many fish **diseases** appear as a result of the **acidity of the water**. In such case, if the water is rich in iron, it turns into a **colloidal iron** that settles on **the gills**, making breathing is difficult. Therefore, experts advise the need to **add** an amount of **calcium carbonate estimated at 0.5 tons / Ha.**

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5. **Alkalinity of water:**

It is a measure of the amount of **carbonates and bicarbonates (alkalis) in** the water. Alkalinity suitable for normal fish growth is estimated in the range of **50 to 200 ppm.** Its value can be improved **by adding lime**.

Alkalinity can also be determined by the pH (pH indicator). The number **9 on the pH is an indication** of the **risk** to fish life. This value usually results from **contaminants**, as well as from tanks if these **concrete tanks** are still new.

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6. **Ammonia ratio:**

Ammonia is **the biggest concern for fish farmers**. It is one of the most problems that appear in fish farms, **suffering rapid and mass death** of fish or serious damage to the structure of fish.

Some of the problems that fish are exposed to when ammonia is high in ponds are:

- Fish **death**.
- No fish **growth**.
- Negative effects on **gills, kidneys and brain**.

Therefore, attention should be paid to **indicators** of **high concentration of ammonia** in ponds, including:

- **No appetite** to food.
- The **appearance** of an unusual **smell** of water.
- Fish **jump out of the water**.
- Change in fish behavior.
- **Inactivity** and change in fish **movement**.

Disposal of ammonia in achieved through **water recycling**. Water is introduced at one side and taken out **from the opposite side.** In addition**, reducing the pollutants to the minimum extent** is also effective. Therefore, one must make sure that the concentration of ammonia in ponds does not exceed **0.5 mg / l.**

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7. **Water hardness:**

It is a measure of the **concentrations of calcium and magnesium ions.** Water is hard water when it contains many of these ions. It is also highly correlated with pH and alkalinity. Both rates are influenced by the addition of lime (liming process). Experts estimate the best fish growth rate **between 50 - 300 ppm.**

It is known that almost all governorates in Egypt suffer from high rates of water hardness, **especially Kafr El-Sheikh**. Therefore, one should avoid the use of lime in disinfecting processes of the pond, as it raises the rates of water hardness.

8. **Rate of toxic substances and substances:**

Their presence in aquaculture water with certain proportions called the **"lethal ratio"** leads to the **death** of fish. However, their presence at rates below this fatal rate affects fish health, but in varying proportions, depending on the species. The effects are as follows:

- **Accumulate** in the body **tissues** such as the liver, gills, heart, spleen and bone causing physiological and functional changes to these organs.
- Affects **fertility** and thus lead to a **decline in reproduction rates.**
- May lead to **distortions** in **fish and fish seeds.**
- Affect the composition and function of **the gills**.
- Increases the **genetic predisposition** of fish to catching diseases.

1.3.3 Location.

The appropriate location of the fish farm should be chosen taking into account the **specifications** and **conditions** that lead to the **success** of the project and reduce the **costs** necessary to address the **problems** that may be identified in the **future**.

When **choosing a location for a fish farm**, consider the following:

1. Be **close** to the **water source**.
2. Water should not leak through it in case of using **basins.**
3. Be **far** from agricultural and human **waste**.
4. Be easily accessible.

Fish farming is **the third source of fish in Egypt** after the seas and lakes. Farming projects have developed in Egypt **since 1970,** with an area of about 250,000 feddans. Most of these lands in Egypt are located next to the northern lakes and northern shores of the Mediterranean.

Factors that promote the trend towards aquaculture in Egypt:

1. Nile water and its tributaries that penetrate in various parts of Egypt.
2. Availability of **wastelands**, natural ponds in lowlands.
3. The need to increase the rate of production of protein food due to the **increase in population.**
4. Availability of the necessary seed to compensate for the shortage of fish in their natural environment.
5. Providing a **source of hard currency** through exporting.

Conditions for the establishment of a fish farm:

1. A **source of pollution-free water** is a must. **Well or spring water** can be used. **Canals and rainwater** can also be used. The amount of water the farm needs can be estimated from the following formula:
   (Pond area × depth of water in ponds) + daily loss ratio x rearing period.
2. An appropriate location for the farm is a location **close to water sources.**

1.4 Forms of aquaculture.

i- Fish Farms:	Fish farms are ponds in which fish seeds are placed in the water suitable for their livelihoods. They may be **concrete or soil-bottom.** They allow **the control of the water flow and supply** during the various stages of breeding. They also allow **the control of the nutrition** needed for the fish in the pond.
ii- Fish Cages:	A cage is one of the means of raising fish **in its natural environment.** It uses a cage or a **floating box consisting of a wooden frame, a net and a yarn** that contains the seed suitable for the type of water, whether it be a sea or a river. **Appropriate food is provided continuously to the fish.**
iii- Fish breeders:	They stand for exploitation of **land adjacent to the lakes or some parts of the lakes** and supplying them with appropriate seed, with the addition of appropriate fertilizers to increase fertility.

1.5 Stages of planning and designing a fish farm.

Stages of Fish Farm Design and Planning:

<u>The first step:</u>

The wastelands, that not suitable for agriculture and are located in the center of agricultural areas, are used for fish farms. First, a sketch and a general vision of the farm is made. That sketch must specify:

- its various sections, with the determination of **the number of ponds, types, sizes and forms**
- and the system of **feeding and drainage water**.

<u>The second step:</u>

A study is carried out on **the depths** and **the side of the pond inclination.** The areas of the ponds **are marked on** the land on which the farm is to be constructed. A **storehouse** must be created to store the food.

After the completion of these two steps, the shape of the ponds is determined according to the fish farming system used, which is one of the following systems: **intensive, intensive, semi-intensive.**

1.6 Breeding systems of fish farming.

1.6.1 Intensive breeding system.

Intensive aquaculture can be defined as raising fish in large numbers in a small area. It requires constantly changing water to ensure its **quality**. In addition, **proper ventilation** is needed in order to to address the problem of **lack of oxygen** dissolved in water. This lack of oxygen becomes a problem when dealing with **large numbers of fish**.

A- Advantages of intensive breeding:

- Needs a **limited water body**.
- Easy farm **control and management.**
- High **production**.
- **Easy disposal** of unwanted **plants and weeds**.

B- Disadvantages of intensive breeding:

- Increase the **manpower** required to operate and manage the farm.
- High **production costs.**
- **Easy spread of diseases**, especially parasitic diseases due to large numbers.
- **I**n the event of **emergencies**, such as **lack of oxygen or the presence of insecticides in the water**, leads to **death of large numbers of fish.**

The one managing the farm should be familiar with **all technical and administrative matters**. A decent share of information with regard to monitoring the properties of water, its impact on fish, dissolved oxygen in water and the impact of its lack on the growth and life of fish. Oxygen measurement should be done regularly every morning (at least). **The lack of oxygen** is observed by **fish at the surface of the pond, opening and closing their mouths and gills continuously**. Therefore, it is a must provide oxygen either through **oxygen machines** or **draining** part of the water and **compensating** it with new water. In conclusion, The intensive farm should be equipped with **oxygen machines, backup generators and the necessary instruments to measure the concentration of oxygen, PH and salinity.**

1.6.2 Extensive breeding system.

The use of an **extensive aquaculture** system depends on the **availability** of **large bodies of water in which a large number of fish are properly stocked.** The availability of stock in these farms depends on the **natural breeding of fish**.

A- Advantages of intensive breeding:

- **No** significant **change in water properties**.
- **No need for too much human power**.
- No need to **divide** the farm into **ponds**.
- **Reduced fish disease** occurrences.

B- Disadvantages of intensive breeding:

- **Difficulty in controlling or disposing** of existing aquatic plants.
- **Lack** of **production**.
- **Difficult to harvest** where it is difficult or impossible to dry the farm.

1.6.3 Semi-intensive breeding system.

Semi-intensive aquaculture is a system between intensive and intensive aquaculture, i.e. **less water available than extensive and more than intensive, and higher density of fish than in the extensive system and less than intensive.**

1.7 Classification of fish farm ponds.

The fish farm is divided into a **number of target ponds,** each has a **specific function**. The **area** of these ponds depends on the **targeted production** quantity. In general, when creating a fish farm that includes all stages from **spawning to marketing**, the farm must contain the following ponds:

1- **<u>Mothers' ponds:</u>**

Mothers' ponds constitute approximately **3% of the total area** of the farm. Mothers are used for **spawning and producing Larvae**. They ponds are also where these mothers are **stored during the winter season**. **Depth** of these ponds ranges **from 100-130 cm** so that fish are not affected much by lower water temperatures. **As the the temperature gets lower fish usually go to the bottom of the pond**.

2- **<u>hatchery ponds:</u>**

In general, the area of hatchery ponds **is approximately 1%** of the area of the fish farm. The area devoted to hatchery ponds is divided into **small ponds ranging between 10-100 square meters**. It is where **males and females** are placed at a certain rate in the case of **natural spawning**. For example, we place **One male for every three females** in case of the **tilapia** fish. After spawning, the **fish seeds or larvae** are left for about a week, then collected and transferred to the **nursery ponds**.

3- **<u>Nursery ponds:</u>**

The nursery ponds constitute **approximately 5%** of the fish farm area. These ponds receive larvae of fish coming from the hatchery ponds. **These larvae** are incubated in the ponds under **appropriate conditions** to **reduce the loss percentage to the lowest degree possible.** The larvae remain in these ponds for a while and before being transferred to the **breeding ponds.**

4- **<u>Breeding ponds</u>**:

Breeding ponds constitute **approximately 10%** of the area of the fish farm. These ponds are devoted to raising small fish until they reach **a certain size.** After that, they are transferred to the **fattening ponds. In many farms the breeding ponds are not established but are transferred directly from the nursery ponds to the fattening ponds.** The breeding ponds themselves are used as fattening ponds.

5- **<u>Fattening ponds</u>**:

Fattening ponds cover **most of the fish farm area**, accounting for **approximately 70-80%** of the total area of the farm. In these ponds, fish are grown **to market size.**

6- **Selling ponds:**
These ponds are used for storing **alive ready-for-sale fish.**

1.8 Classifications of fish farms.

It is important to choose the type of the fish farm that is suitable to both **location and water supply availability** as previously discussed. Many classifications are due in this accord. We present 2 of these classifications below.

1.8.1 Classification of fish farms **according to water type**.

Fish farms are divided according to water type into:

1- Waste water farms:

These farms receive their water from **drains that pour into lakes** such as **Manzala, Burullus, Edku and Mariout**. Therefore, hese farms spread alongside the **end-irrigation lakes**.

2- Freshwater farms:

It is the **best type** of fish farming, as there are lots of fish that are suitable for this type of breeding. It also gives **better growth.**

3- Salt water farms:

This type of farm is spread **on the Mediterranean coast between Lake Manzala and the Mediterranean Sea and north of Lake Burullus** and **the northern coast near Damietta.** This type relies on **sea water,** especially on the Red Sea and the northern coast.

4- Brackish water Farms:

The brackish water is a **mixture of fresh and salt water.** This type of farm is found in the **northern regions on the sides of Manzala Lakes, Burullus, Idku and Mariout.**

5- Rice fields farms:

It is a type of **seasonal fish farming**, which is done in the rice fields. The surplus production is marketed in order to achieve **a suitable profit** for the **farmers**.

1.8.2 The **accurate** classification of fish farms.

The previous classification only gives an incomplete discription

1.8.2.1 Growing fish in ponds

The methods of caring for fish within ponds differ as follows:

A- Single Type ponds:

They are ponds in which **one type of fish** is raised and are often **one of the species that feed on animal proteins** such as snakes and catfish. It is also possible to breed **grass-eating or multi-feeding** species. The best fish for this method are **carp, mullet and tilapia**.

B- Multiple types of basins:

They are ponds that accommodate **different types** of fish, which may vary in age. For example, farms where the types of **(Chinese and Indian carp), (tilapia with carp) or (milkfish with shrimp)** are raised.

C- Intensive Care ponds:

They are **small ponds** in which **scientific methods and modern technologies** are used. Ponds are planned for construction, use of **high-value industrial fodder**, **oxygen-supplied water**, and **wastewater purification.** This type of pond costs large sums of **money**, but in return it achieves abundant **profit**. The only disadvantage of this type is what accompanies **technical faults** or **diseases** that may affect fish. This type of farm is used in **advanced industrial countries** to produce fish with a high marketing value such as **salmon, tarot, snake, and catfish.** This type of pond is characterized by **large fish stocking density**.

D- widespread care ponds:

They are ponds with low storage density. They are characterized by a **low rate of production per unit area**, and fish in them feed on **natural food.** This type of pond does not suffer from the problem of **water quality**. It is compatible with **poor countries** (it doesn't require a large capital of money), as it is an intermediate source in terms of providing fish production and employment.

E - semi-intensive care ponds:

They are ponds that are used in **almost all countries** to produce types of **grass-eating and multi-feeding fish**. Fish get their food from **natural food** and additives from **plant and animal waste**. **Fertilizers** can be used to increase production. This type is suitable for increasing fish production rates in **developing countries.**

F- Recycling ponds:

They are ponds in which **animal and plant wastes** are used, as fish is fed the remnants of **terrestrial animals**. This type belongs originally to **Asian countries,** and has widely spread in all countries of **Asia, Eastern Europe, North Africa and Nepal. Ducks and cattle** are raised next to these ponds to use their waste to fertilize the fish ponds, which is an **efficient method** for getting rid of pollution from animal waste. The only flaw of this type is that it may be a source of **transmission of pathogens** to **humans**.

1.8.2.2 Fish farming in tanks.

Tanks of 3050 liters are used for this, with a speed of recycled water flow of **220 liters per hour**, or larger tanks of **up to 12 thousand liters and a water flow rate of 1 liter / kg / s**, for the purpose of producing 850 kg of fish. The flaws of this type are: **high rates of water waste** and **low oxygen levels.** Toxic waste that affects fish growth significantly.

1.8.2.3 Fence or mesh barriers farms.

Fences are used to control the breeding of different types of fish, whether in **fresh, salt, or in brackish water**, in **intensive, semi-intensive, or extensive systems**. The mechanisms depend on the type of fish and farm system just like in **pond fish farms.**

The **sizes of fences or mesh barriers** vary according to **environmental** conditions, **water** features and **fish species**. Fences or barriers are erected in places where farms are not suitable for construction. They are mostly built **on beaches and within lakes and rivers.**

1.8.2.4 Irrigation canals and rice fields.

Fish farming was established in **Asia** for a long time in **irrigation canals and rice fields**. It is known that rice fields produce **plankton** in large quantities, which makes them fertile and a good **food source** for the fish. plankton helps fish produce additional **protein**. This method is used for fish with the ability to withstand water conditions **shallow, high temperature, low oxygen,** such as **tilapia, carp, and catfish.**

It is possible to have **different types of fish** inside these farms. **Fresh shrimps and shellfish** can be brought together, as they all have **beneficial effects** on the rice crop. This allows **control** of **unwanted plants, snails and insect larvae**.

Alternative methods **other than pesticides** should be used. **Overuse of pesticides leads to problems on the farm.**

1.8.2.5 Breeding fish in **bilge water**.

Bilge water is a type of water characterized by a degree of salinity. It may be **wastewater or well water** that is **not suitable for irrigating field crops.** The **salinity** of this water **varies from season to season**. It may decrease in the **rainy season** to **5 parts / thousand**, and rise in the **dry seasons** to reach to **70 parts / thousand.**

In bilge water**, tilapia, catfish, mullet, carp, milk, head of serpent and shrimp** are bred.

1.8.2.6 **Running water** farms.

Running water is characterized by being **rich in oxygen**. This allows **increasing the density** of fish per unit area, and also helps in getting rid of **fish waste.**

1.8.2.7 **Water circulation system farms**.

These farms are one of the best ways to obtain **intensive production of fish**. It was recently developed in a number of major **industrialized countries** because of the severe need for good water, and to achieve good **drainage from the farm to public drainage**. This type of farm is applied to **high-value aquatic fish.** Due to its high cost in terms of **construction systems and superior maintenance,** it is characterized by:

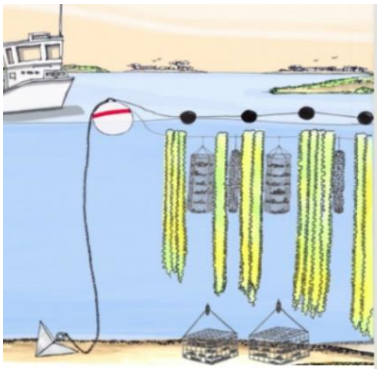
- the same advantages and disadvantages of **intensive production**
- being **energy-saving,** which is appropriate for the conditions of developing countries.

This method is used to:

- **control the maturity** of fish, crustaceans and shellfish.
- **produce youngster**s in an easily controlled environment.

1.8.2.8 **Shellfish vertical production** farms.

This method was recently introduced for the breeding of **Umm Al-Khulool and oysters**. It helped in increasing production, as shellfish is grown on **sticks and ropes hanging from the roofs** and in **nylon nets** in the form of **pods** or in **plastic pots or wooden frames.**



It is known that the breeding of **Umm Al Khuloul and oysters** was taking place **on the sea floor**, but it may be difficult to use these floating systems due to the difficult sea conditions. However, the **oyster farms** with the long rope system are still effective.

1.8.2.9 **Marine** farms.

They are farms in which fish, shrimp and shellfish are raised in **hatcheries** until the time when they can **depend on themselves for feeding**. Only then, they are spread in open water environments, until the time for **fishing**. despite the difficulty of that, however, this type of farm is considered profitable by experts In certain circumstances, it is possible to increase the harvest from ordinary fishing, and it is also an organized method of storage.

1.8.2.10 **Mixed Production** Farms.

In addition to fish production, this type includes the production of **rice or a type of animal,** such as duck, on or near the surface of the pond. It is characterized by the following:

- **Duck waste** is used to fertilize the water of the **pond, as** it is considered an **organic fertilizer** that develops **plankton**.
- **The rest of the duck food** is used to feed the fish, or is used as an organic fish fertilizer.
- Ducks feed on **snails**, which limits the spread of **bilharzia**.

1.9 **Preparation and maintenance** of ponds.

1.9.1 Drying ponds.

This is done **by completely draining** the pond from the water. We get rid of the **plants and other harmful microorganisms** present in the pond. We also remove the compounds and **materials** that may have been **deposited at the bottom** of the pond as a result of **organic decomposition**. These substances are oxidized once exposed to the air. **Maintenance** of the pond is then performed in case of any defect in it.

1.9.2 Filling the ponds with water.

During this process, the following consideration should be taken:

- Placing barriers at the **entry of irrigation and drainage channels** to prevent entry of plants and herbs into the basin, as well as preventing fish from leaving them.
- Making sure the barriers are **not completely blocked** by plants and hers, as this may break the barrier.

1.9.3 Monitoring the quality of water.

The quality of farm water is maintained by checking the characteristics of the water previously explained **at a regular basis**.

1.10 **Manufactured feeds**.

Manufactured feeds are an **indispensable** necessity in the case of **intensive fish farming.** However**,** in the case of an **extensive or semi-intensive** system, fish get a portion of their **food from the surrounding natural environment**. Thereby **reducing** their need for manufactured feeds. The use of **organic fertilizers** in **semi-intensive** fish farms leads to increase the production of natural food (**plankton**), thus less fish need for manufactured feeds. Industrial feeding accounts for **approximately 50% or more of all farm costs**.

Generally, with regard to fish feed, the following specifications are required:

- **containing the nutrients,** the body needs **protein, fat, carbohydrates, vitamins and minerals.**
- being **accepted by fish**.
- consisting of **permanently available components (locally if possible).**
- being **easily manufactured and stored.**
- being **inexpensive**.

- Not containing **harmful substances** to fish, such as **pesticides, microbes and toxins.**

As for **the basic components** of fish feed, the industrial feed for fish must contain **protein, fat, carbohydrate**, **vitamins, minerals and mineral salts**. It should be noted that **fats and carbohydrates** are the main **source of energy,** while **protein** is the main **building block of the body**.

1.10.1 Protein.

Protein represents the **basic building block** of the living organism. Proteins are made up of units called **amino acids** that group together in a **chain**. The **type of protein** depends on the **numbers** and **types of amino acids**. The amino acid is mainly composed of **carbon, hydrogen and nitrogen**. The protein amino acids are divided into **essential and non-essential amino** acids. We will briefly discuss the main protein sources for fish feeds.

1.10.1.1 **Animal protein**.

Animal protein is the **most valuable** source of protein in terms of **containing essential amino acids**. However, the main problem facing the use of animal protein in fish diets is **the high price and low production**. Hence, it is necessary to **calculate the amount of animal protein that the feed should contain accurately**.

Fish meal, poultry waste, slaughterhouse waste, blood powder, fish waste and snails are among the most important sources of animal protein used in fish diets.

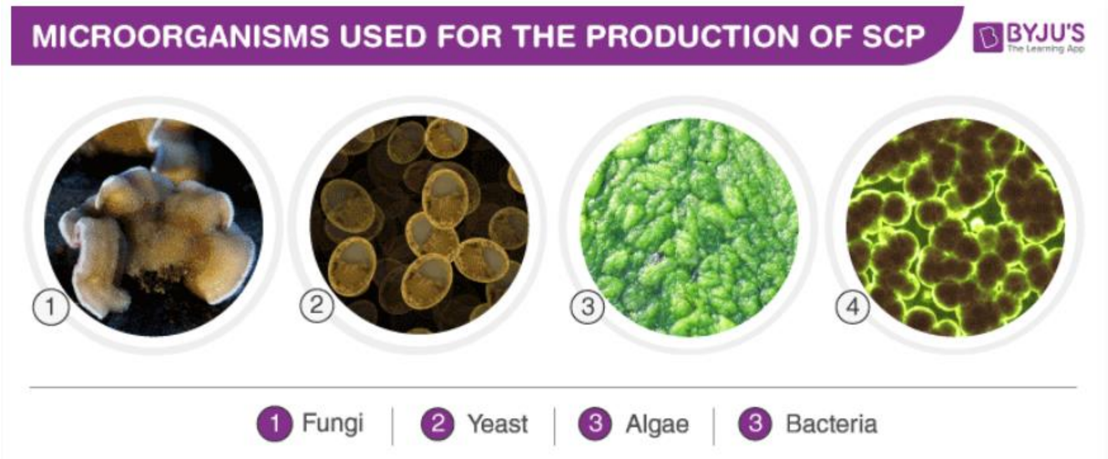
The quality of the protein varies according to its **source** and **content** of **amino acids** and the **method of preparation and storage**. **Fish meal** is the finest animal protein, as it contains high amounts of **all essential amino acids** compared to other sources.

1.10.1.2 **Vegetable protein**.

Oil crops such as **soybeans, cotton-seed, sunflower**-**seed and sesame** are among the primary sources of vegetable protein, **after squeezing seeds and extracting oils from them.** The seeds of these plants contain a high percentage of most of the **essential amino acids**. **Chlorella, aspirin and sea lettuce** are also good sources of vegetable protein. However, it is worth noting that some plant protein sources lack **lecithin acid** and therefore this acid must be added when used as a source of protein in the diet of farmed fish. In general, **missing acids are often added** by adding another source that contains the amount of these acids.

1.10.1.3 **Single-cell protein**.

This protein is produced (as evidenced by the name) from **unicellular plant or animal** sources such as **yeast, algae** and **primary single-celled animals**. It is known that these organisms **multiply and multiply** their number millions of times in short periods of time. Therefore, they can be intensively and in a narrow space for use in feeding Fish, especially in **the early stages** of life (**the larval stages**). These creatures are characterized by having a **high percentage of protein** and therefore can be added in different proportions to the manufactured feeds of fish.



1.10.1.4 **Industrial and agricultural waste.**

Many **industrial, agricultural, and other wastes** are important sources of protein for fish. **Food industry wastes** such as waste for the manufacture of juices, preserved foods, yeast, and starch contain varying proportions of **vegetable or animal protein**. Therefore, they can be added to **fish feeds** in certain proportions according to **fish farming conditions and protein content**.

1.11 Executive Procedures for Fish Farming Projects.

The government takes great care to **fish wealth projects**, as an **important and inexpensive protein source**. Being a new field, the potential rises for many **unemployed youths** to work in these projects. Therefore, they are considered a source of national income.

Among the food security projects in **the field of fish wealth projects**:

- Establishing fish farm projects.
- Establish **hatcheries** projects for the production of fish seed.
- Fish farming on **rice farms**.
- Fish farming on **rooftops**.
- Advancing **already established farms**.
- Transferring ownership of **floating fish cages** to the youth.

1.11.1 **Dual investment.**

One of the great features of fish farms is that you can use the water of the farm ponds **during the process of changing water** to grow many **agricultural vegetables** next to your **fish farm**. This is because there is a high **fertilization rate** in the water resulting from the **recycling of the water** of these ponds.

Ammonia and waste products are **natural** products that give a **high-quality fertilizer** which is more like **hydroponic** ... This means the establishment of **two projects at one time** to **re-fertilize wastelands.**

1.12 Technical and economic aspects of marine-fish species.

1.12.1 Sparus Aurata (Gilthead Sea Bream).

One of the species spread in the Mediterranean basins. Breeding of sea bream is available in **large quantities mainly in Damietta and Port Said.**

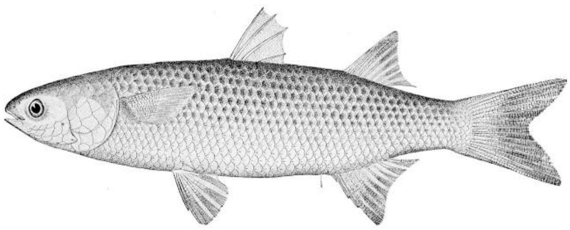
The breeding of this species has succeeded **in Greece, Spain, Italy, France and Portugal**. Due to the success of its **breeding** in recent years, **several hatcheries** in Egypt were founded for the **private and public sector**.

These fish reach the **market size** in a period of **18-20 months** and feed on **damp minced fresh fish and crustaceans** with **high protein and fat content**.

1.12.2 Dicentrarchus labrax (European seabass).

It is a **salt water** fish of great economic importance and is spread in many regions of the world**.** Seabass is characterized by **rapid growth** and reaches the **market size in a period of 18 - 20 months.** The seabass is grown in **floating or thickened cages**. It gives production rates of **up to 40 kg / m3** and some giant rotating flexible cages are given **400 kg / m 3** for a year. They feed on **moist rations from minced fish Crustaceans mixed with vitamins**, preferably **raw protein content not less than 40%,** and **fat content** in fish oil form **not less than 12%.**

1.12.3 Mullet fish.



The fish of the mullet family lives in **fresh water** and **in lakes** and on the **shores of the seas** in hot regions. They feed on **organic materials** present in **the mud** and therefore **their gut is long and twisted**. Fish of the mullet family is spread all over the world. It is considered one of the **economic and popular fish in Egypt** because of its **cheap price** and the **quality of its taste** and **diversity methods of cooking it**. Its production constitutes about **20% of the total fish production from various sources in Egypt.**

1.12.4 Epinephelus Guaza.

The cultivation of this fish is widespread **in Damietta and Port Said**, as it is also cultivated in some farms **in fresh water**. They are considered **very sensitive to handle and transport**. The best growth rates for them in the fish farm were estimated at **2.6-3 g/day**. They feed on **fresh fish and crustaceans** and can be fed with **manufactured fish feeds** with a high protein content of **50% protein** (moist fresh **minced fish and crustaceans** are preferred). The duration of breeding (**from 25 g)** ranges between **10-12 months** to reach a size greater than **1 kg** under the conditions of **the Egyptian environment**. The price of **20-30g of fingerlings** ranges between **7-10 pounds**, and the selling price of **one kilogram** of the market size ranges Between **35-40 pounds**. Egypt **exports** large amounts of the **Epinephelus Guaza fish.**

1.12.5 Argyrosomus Regius (Meagre fish).

The cultivation of meagre fish is spread in the **triangle of El-Diba in Damietta Governorate** (the marine farms of **Shata**) in the Arab Republic of Egypt. The best growth rates in fish farms are an average of **3 g/day**. Their weight reaches about **1.5 kg** in the breeding season of **10-12 months** under the **Egyptian environmental conditions.** The price of fingerlings ranges **within 7 pounds**. The average selling price per **kilogram** of a marketing size reaches **20-25 pounds.**

1.12.6 Eel fish

There are several types of **eel fish**. However only one type (**Anguilla anguilla**) is spread in Egypt. Egypt's production of eel has reached about **800 tons a year**. **Worms and minced fresh fish** are among the best foods available to feed eel fish. They are considered to be migratory fish. They can live in both **salty and fresh water** and are better grown in **brackish water**.

1.13 References.

1.	Article on AQUACULTUE (https://en.wikipedia.org/wiki/Aquaculture).
2.	ARTICLE ON FISH FARMING IN Egypt **(**http://www.fao.org/fishery/countrysector/naso_egypt/ar**).**

Chapter 2

Proposed system structure and components.

2.1 General block diagram of the system.

It was proposed to separate the system into 3 subsystems. These subsystems are as follows:

1- the **MPPT Solar** Subsystem
2- the **Mechanical** Subsystem,
3- and the **Control and IOT** Subsystem.

Each subsystem may have a number of sections. That proposed structure of the system is shown in figure 2.1.

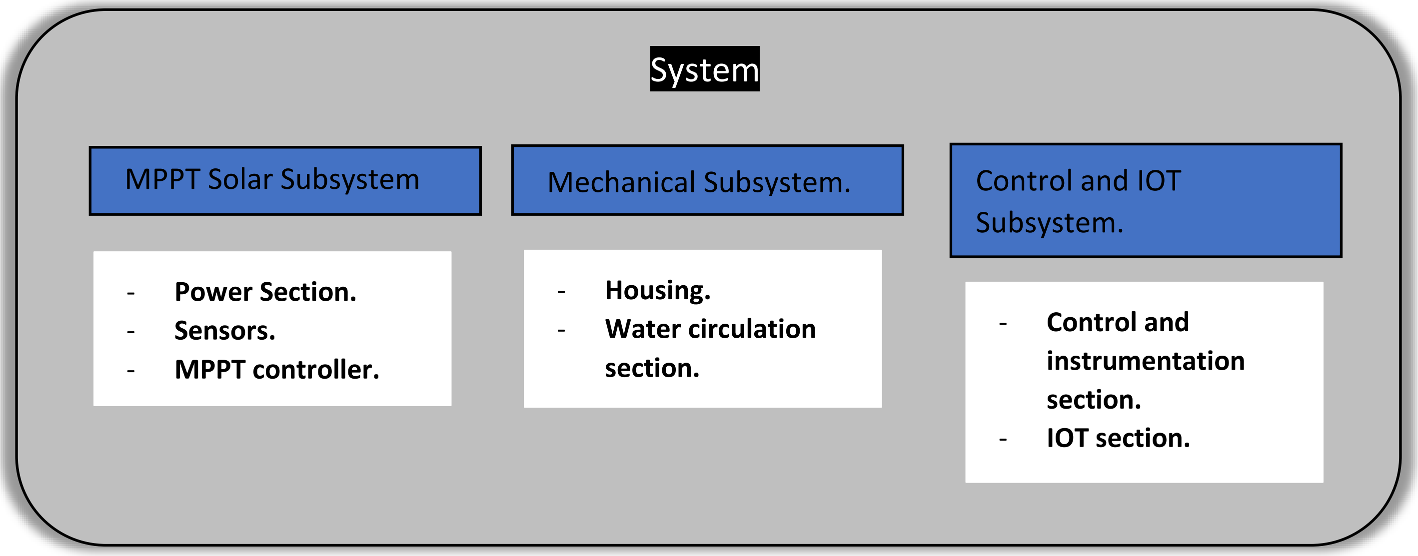


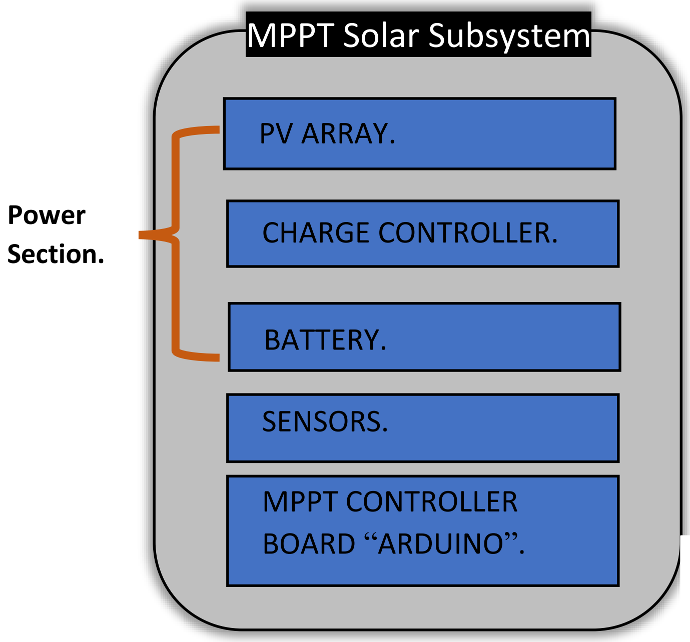
Fig. 2.1 block diagram of the system.

2.2 Overview of the MPPT Solar Subsystem.

2.2.1 Objectives.

- **Extracting the maximum power from the PV array** regardless of the irradiance level and the temperature.
- **Charging the battery efficiently** in a way that doesn't reduce the life time of the battery drastically each cycle.
- **Providing uninterrupted power** to all the actuating and control components of the system.

2.2.2 Functional block diagram.



The solar subsystem has **5 main components:**

1- the PV array,
2- the charge controller,
3- the battery,
4- sensors,
5- and the MPPT controller.

These components are structured as shown in fig 2.2. The table below shows the basic functions of each of these blocks.

Fig. 2.2 Block diagram of MPPT Solar Subsystem.

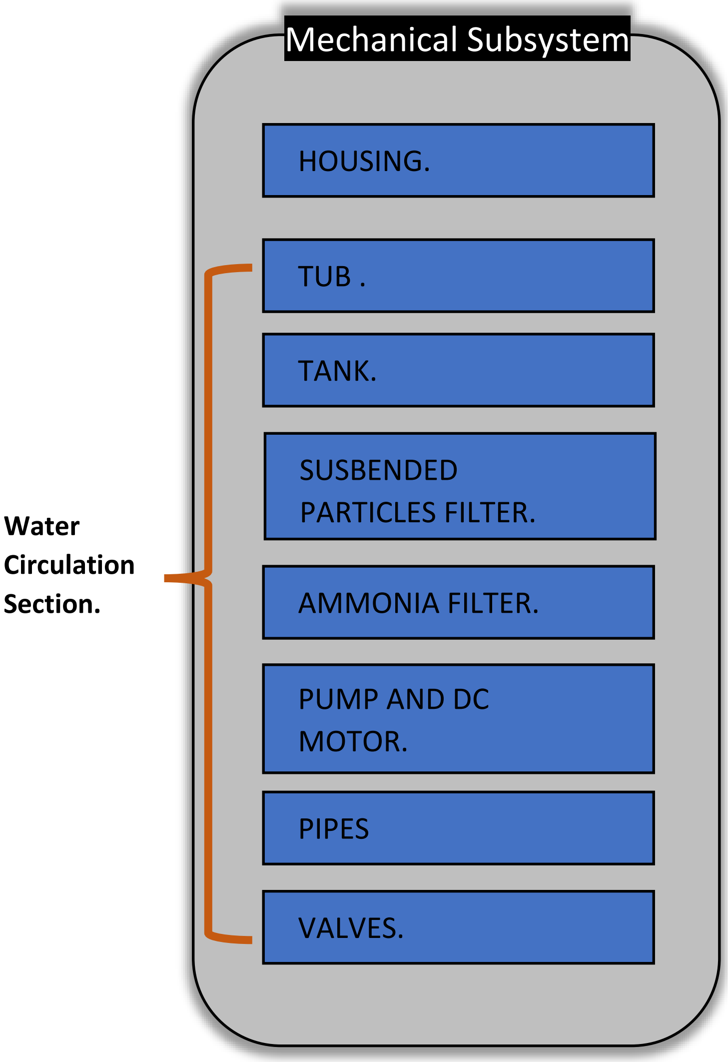
BLOCK	FUNCTION
PV ARRAY.	- **Supplying the actuating and control components of the system** in case the solar resource is available. - **Charging the battery.**
BATTERY.	- **Supplying the control components of the system** during the night. - **Ensuring continuous power supplied to the system** for a few days "days of autonomy" of solar resource absence.
CHARGE CONTROLLER.	- **Keeping the PV array running at maximum power point** regardless of loading and environmental conditions **"MPPT CONVERTER".** - **Controlling the voltage on the load "LOAD REGULATION CONVERTER".**
SENSORS.	- **Providing current and voltage measurements** to the **MPPT CONTROLLER ARDUINO BOARD**.
MPPT CONTROLLER BOARD "ARDUINO".	- **Executing the MPPT ALGORITM.** - **Providing control signals to the charge controller.** - **Sending measurements to the main controller of the system.**

2.3 Overview of the Physical and Water Circulation Subsystem.

2.3.1 Objectives.

- **Housing and organizing** all the components of the system.
- **Providing efficient water circulation** in the system in order to:
  - **compensate for evaporation** in the tub,
  - and **perform necessary filtration** on the tub water.

2.3.2 Fundamental components.



The Mechanical Subsystem has **8 main components:**

1- the housing,
2- the tub,
3- the water tank,
4- the SUSBENDED PARTICLES FILTER,
5- the AMMONIA FILTER,
6- the pump,
7- the pipes,
8- and the MPPT controller.

These components are structured as shown in fig 2.3. The table below shows the basic functions of each of these blocks.

Fig. 2.3 Block diagram of the Mechanical Subsystem.

BLOCK	FUNCTION
HOUSING.	- **Neat and effective housing** of all the system components.
TUB.	- **Containing the fish.**
TANK.	- Supplying water to the tub to **compensate for evaporation.** - Supplying clean water to the tub to **compensate for filtration.**

	- **Providing a sufficient head level on the pump to be able to raise the required water to the TUB.**
SUSBENDED PARTICLES FILTER.	- **Filtering out the suspended particles** from the water drawn from the tub **during the water filtration cycle (resulting mainly from fish food).**
AMMONIA FILTER.	- **Filtering out the ammonia** from the water drawn from the tub **during the water filtration cycle (resulting mainly from fish poop).**
PUMP AND DC MOTOR.	- **Circulating the water in the whole system "ONE SWITCHED PUMP".**
PIPES.	- **Connecting the water network components together.**
VALVES.	- **Switching the pump** to operate between different sections of the system.

2.4 Overview of the Controller and IOT Subsystem.

2.4.1 Objectives.

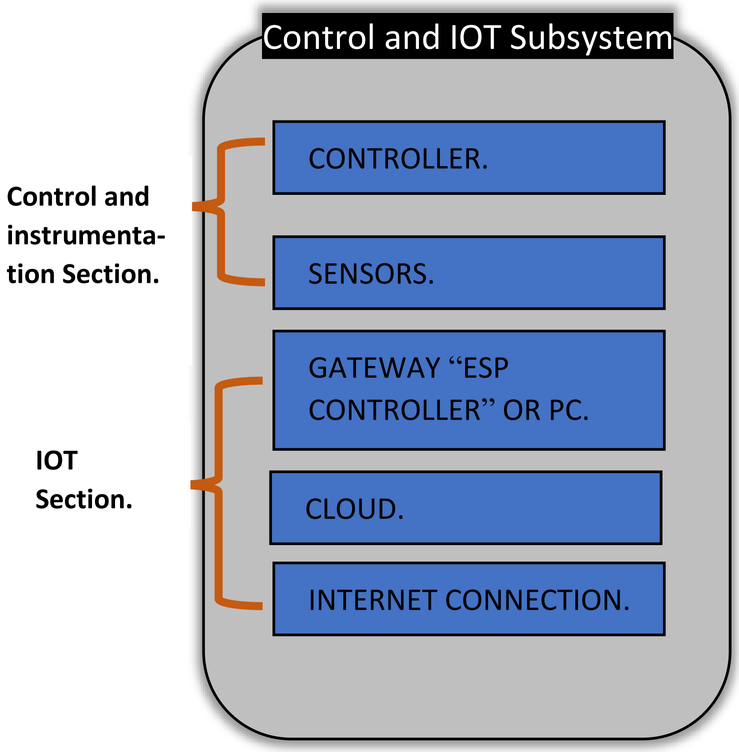
➢ **Objectives of the Control and instrumentation Section:**

- Taking measurements of the system sensors (temperature, level, ………) and from the MPPT CONTROLLER.
- Using the measured system parameters to control the system (decision making).
- **Scheduling of the different periodic tasks of the system.**
- **Communicating back and forth with the gateway of the iot section** (Sending data to the gateway – and receiving commands).

➢ **Objectives of the IOT Section:**

- **Providing a connection between the controller and the cloud through the gateway of the system** (ESP CONTROLLER or PC).
- Providing an **interface for the user** to **remotely**:
    - **monitor** the system parameters.
    - **receive warnings** that require user intervention.
    - **issue commands** to the system when needed.

2.4.2 Fundamental components.



The Mechanical Subsystem has **5 main components:**

1- the main controller
2- the sensors,
3- the gateway,
4- the cloud,
5- and an internet connection.

These components are structured as shown in fig 2.4. The table below shows the basic functions of each of these blocks.

BLOCK	FUNCTION
MAIN CONTROLLER “TIVA C BOARD”.	- **Taking measurements** from the sensor. - **Decision making based on measurements.** - **Running the scheduled tasks of the project** by sending control signals to control the system accordingly. - **Managing communications in the control and instrumentation section.**
SENSORS.	- Taking physical measurements and sending the data to the controller.
GATEWAY “ESP CONTROLLER” OR PC.	- Managing communications between the main controller and the cloud.
CLOUD.	- **Providing a proper user interface to the user.** - **Providing massive data storage capability (logging).**
INTERNET CONNECTION.	- Providing connection between the gateway and the cloud.

Chapter 3

Design of the proposed system.

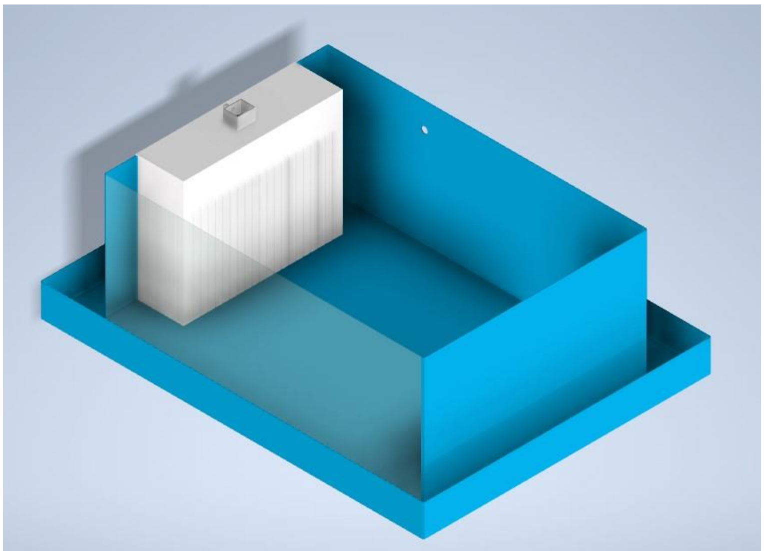
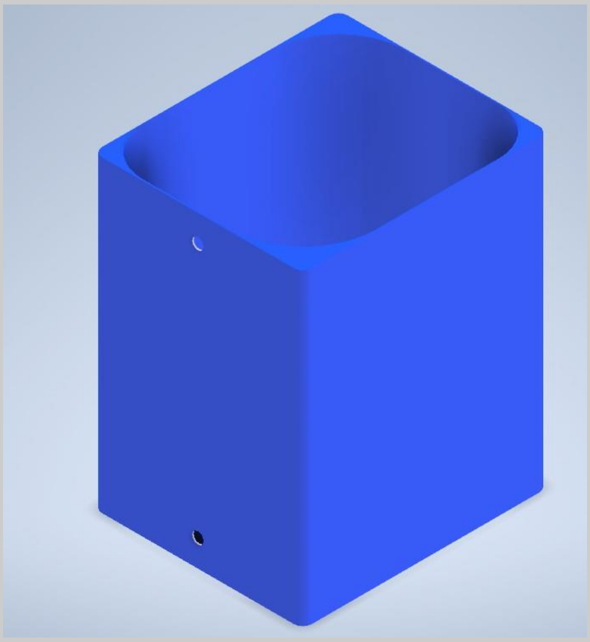
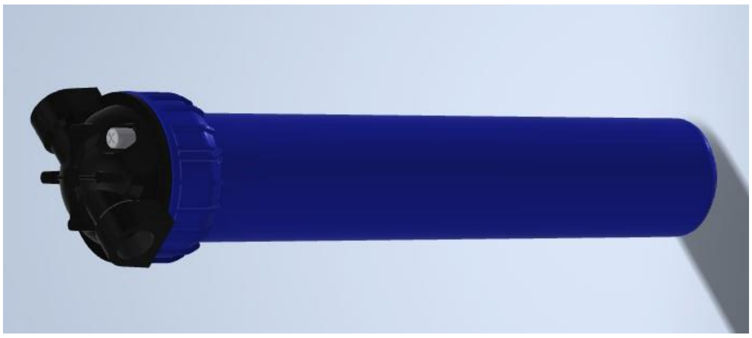
3.1 INVENTOR design of the mechanical components.

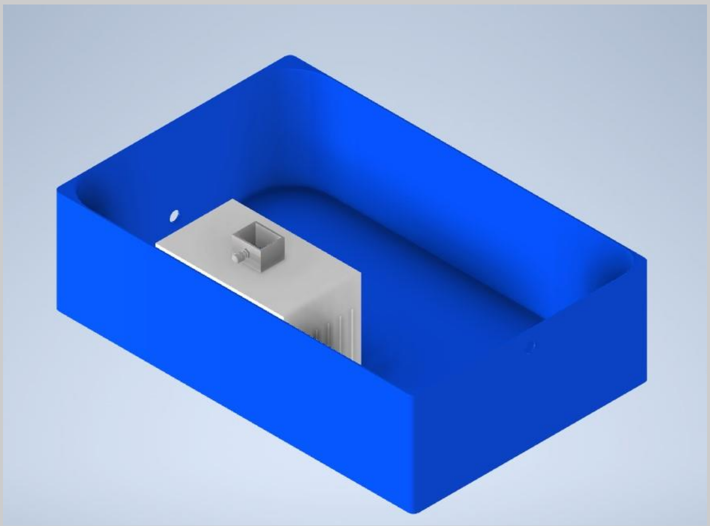
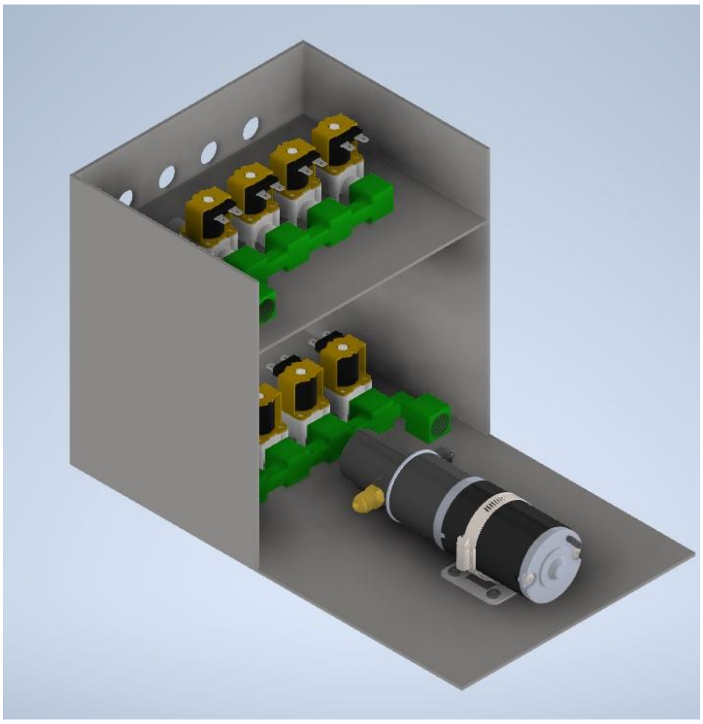
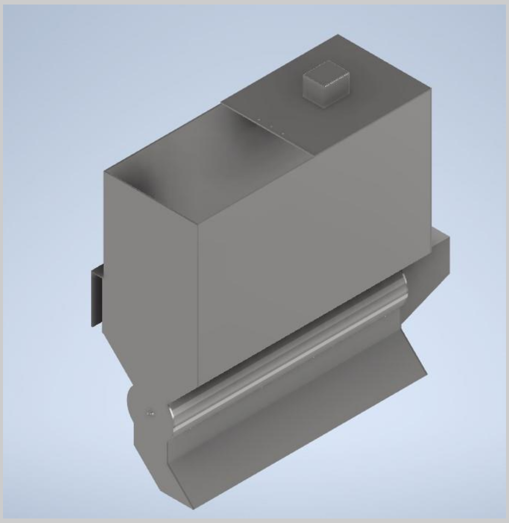
The **AUTODESK INVENTOR** software is **3D CAD software tool** that **offers professional 3D mechanical design and simulation tools**. This software was used to design the mechanical system components. In the following to sections, highlights of the INVENTOR design are presented.

3.1.1 Design of each component.

The table below lists the INVENTOR designed components with a 3D view.

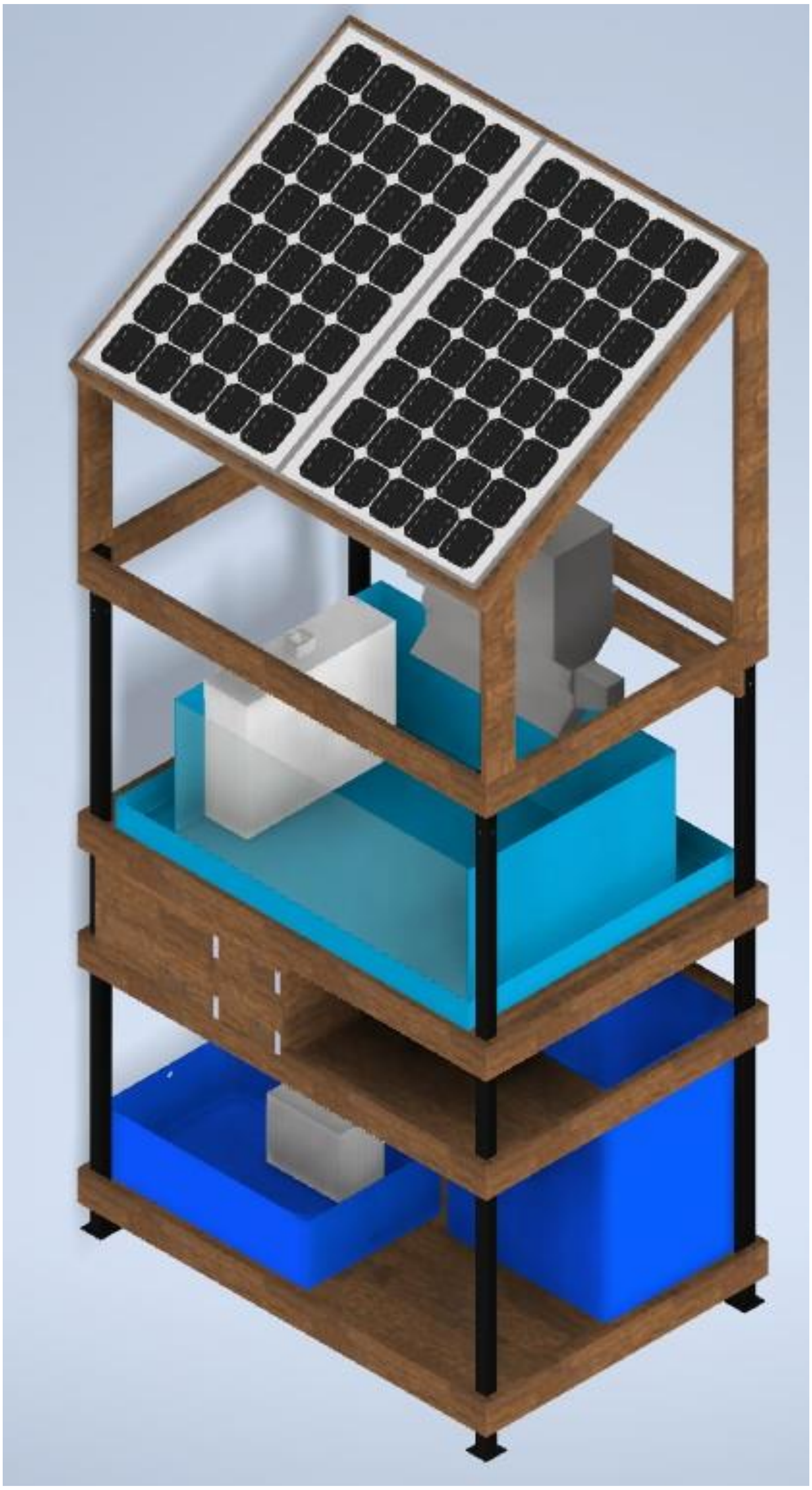
COMPONENT.	3D VIEW.
PANELS HOLDER: • **MATERIAL:** WOOD • **FUNCTION:** FIXES THE PANELS AT 30 DEGREES FOR THE HORIZONTAL PLANE.	

TUB: • **MATERIAL:** fiber glass and glass (1 side). • **FUNCTION:** houses the water, fish and tub sensors. **SENSORS BOX:** • **MATERIAL:** PVC. • **FUNCTION:** keeps the sensors and the suction away from the fish.	
STORAGE TANK: • **MATERIAL:** PVC. • **FUNCTION:** supplies water to the tank for filtration and compensation of evaporation.	
SUSPENDED PARTICLES FILTER: • **MATERIAL:** -- • **FUNCTION:** filters any suspended particles before supplying the water to the ammonia tank.	

AMMONIA FILTER: • **MATERIAL:** PVC. • **FUNCTION:** filters the ammonia before returning the water to the storage tank. **SENSORS BOX:** • **MATERIAL:** PVC. • **FUNCTION:** keeps the level sensor away from the rocks.	
WATER PUMP: • **DISCRIPTION:** positive displacement water pump. **VALVES:** • **DISCRIPTION:** solenoid water valves. • **FUNCTION:** cycle selection on the pump side. **SENSORS BOX:** • **MATERIAL:** PVC. • **FUNCTION: keeps the level sensor away from the rocks**	
Food tank: • **MATERIAL:** stainless steel. • **FUNCTION:** supplies fish food to the tub. • **MECHANISM:** SERVO-CONTROL mechanism.	

3.1.2 Assembling the components in a 3D model.

The 3d view of the entire mechanical system is shown below.

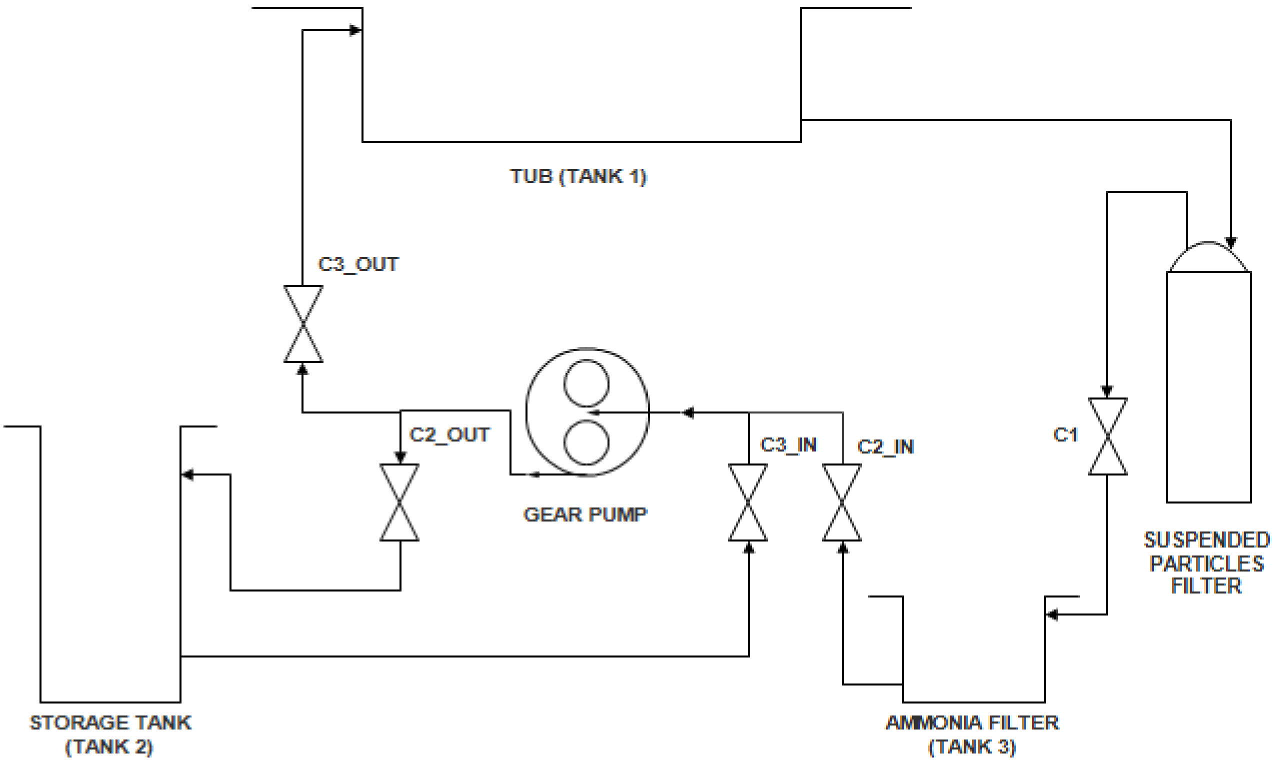


3.1.3 Specifications of other purchased components.

The table below lists the purchased mechanical system components.

COMPONENT.	TECHNICAL SECIFICATIONS
VALVES (X5) **"SOLINIOD VALVE"**	- **12V solenoid valve.** - **180 degrees (x4).** - **90 degrees (x1).**
Pump (X1) **"HITACHI BP-290-II"**	- 24V DC - Positive displacement. - Gear pump.

3.1.3 Design of the water circulation section.



The water flow network shown above was divided into 3 cycles. Each cycle moving water between two tanks. The **first cycle** is working separately with **natural flow against the gravity**. The **other 2 cycles** are working with **forced flow using the pump**. The 2 cycles using the pump must operate separately.

3.2 Design of the MPPT Solar Subsystem.

3.2.1 Load analysis.

Since we have no ac loads, there is no need to do the AC load analysis. The DC load analysis can be carried out as shown in the following **DC load analysis spread sheet** shown below.

DC Load Description	Quantity	Run Watts	Hours/Day	Days/Week	Total Watts	Total Whrs/Day	Total Whrs/Week
Dc Pump	*1*	60	*5.00*	*7.00*	*60*	*300*	*2100*
Valves	*4*	*6*	*5.00/2*	*7.00*	*24*	*60*	*420*
Electronic components	-	*30*	*24*	*7.00*	*30*	*720*	*5040*
Total					*114*	*1080*	
Total Watt hours/day divided by 1000 = kWh/day				*1080/1000 = 1.08kWh/day*			
Total kWh/day x 365 = kWh/year				*1.08 x 365 = 394.2 kWh/year*			

Prototype DC load-analysis spreadsheet.

3.2.2 Sizing the Battery.

The table below lists the steps and calculations necessary to size **a suitable battery bank.**

Design steps	**Calculations**
1. Determine the average daily **AC Kwh consumption level.**	- No ac loads. **Therefore, average daily AC watt-hours of the system is zero.**
2. **Divide the watt-hours value from Step 1 by the estimated inverter efficiency** (usually assumed 90%).	- No ac loads Therefore, this step is skipped.
3. **Add the average daily DC watt-hours** (or kilowatt-hours) consumption level to the watt-hours value in Step 2. This value represents the **total daily energy consumption for all the loads connected to the battery bank.**	DC daily energy consumption of the system is 1.08 kwh. Therefore, **total energy consumption is 0 kWh + 1.08 kWh = 1.08 kWh.**
4. **Multiply the energy value from Step 3 by the desired days of autonomy** to get **the amount of energy the battery bank needs to store** (two or three days is a pretty typical value).	Assuming **three days of autonomy** makes the new energy value: **1.08 kWh × 2 days = 2.16 kWh.**

5. **Divide** the value calculated in Step 4 **by the temperature compensation value provided by the battery manufacturer.** Ninety percent of manufacturers estimate the adjusted capacity at 25 degrees in Celsius.	If the battery bank will be stored at 25 degrees in Celsius: **2.16 kWh ÷ 0.85 = 2.54 kWh.**
6. **Divide the value from Step 5 by the allowable depth of discharge.** The greater the DOD, the smaller the battery bank can be because you'll be using more of the capacity (approximately 50 to 80 percent).	Assuming a **DOD of 75 percent**: **2.54 kWh ÷ 0.75 = 3.39 kWh.**
7. **Divide the value from Step 6 by your desired nominal voltage for the battery bank.** Batteries are rated in amp-hours, not watt-hours. By using the nominal battery bank voltage, you can determine the required amp-hours for the battery bank (use a 12 V, 24 V, or 48 V).	The system will be installed at **12 V**. The minimum capacity of the battery is calculated as follows: **3.39 kWh ÷ 12 V = 0.282 kAh, or 282 Ah.** - **The selected battery must have a capacity higher than this value.**

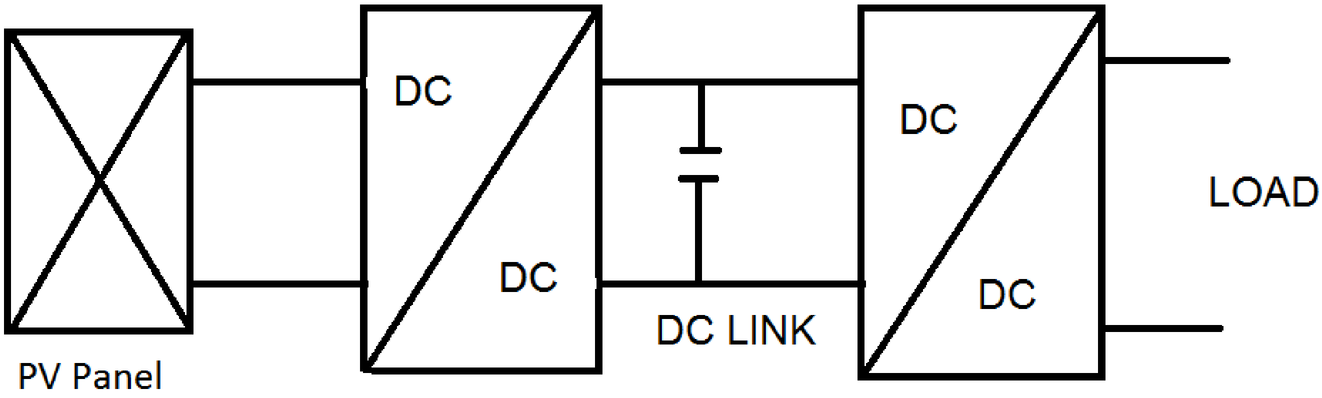
3.2.3 Sizing the PV Array.

The table below lists the steps and calculations necessary to size **a suitable PV array.**

Sequence of operations	Calculations
1. Gather the total energy value calculated in the load analysis. **This was done before while sizing the battery.**	In that example, the total energy consumption (of both AC and DC loads) was 1.08 kWh.
2. Multiply the estimated battery and PV array efficiencies.	**Taking 85% × 75% as our efficiencies, we get 64%.** Even if you choose not to use these numbers, what you wind up with after completing this step is the **total efficiency of the PV array in charging the batteries.**
3. Multiply the efficiency value from Step 2 by the TSRF that you determined during the site survey. consumption level.	We assume a **TSRF of 90** percent (in other words, we lose 10 percent of the potential resource due to shading and the array tilt and orientation). **0.64 × 0.9 = 0.57.**
4. Divide the total energy value found in Step 1 by the total efficiency value found in Step 3.	Doing so gives you the total daily amount of energy the array needs to produce. In this case, that's **1.08 kWh ÷ 0.57 = 1.89 kWh.**
5. Divide the energy value from Step 4 by the peak sun hours value you decided to use.	The result of this equation is **the array size in watts.** So if **the average peak sun hours is 4.2** , the power from the panels should be: **1.89 kWh ÷ 5 = 0.378 kW = 378 W.** - **The selected array must be capable of supplying this value at least.**

3.2.4 Designing the MPPT charge controller.

3.3.4.1 **Overview of the MPPT section.**

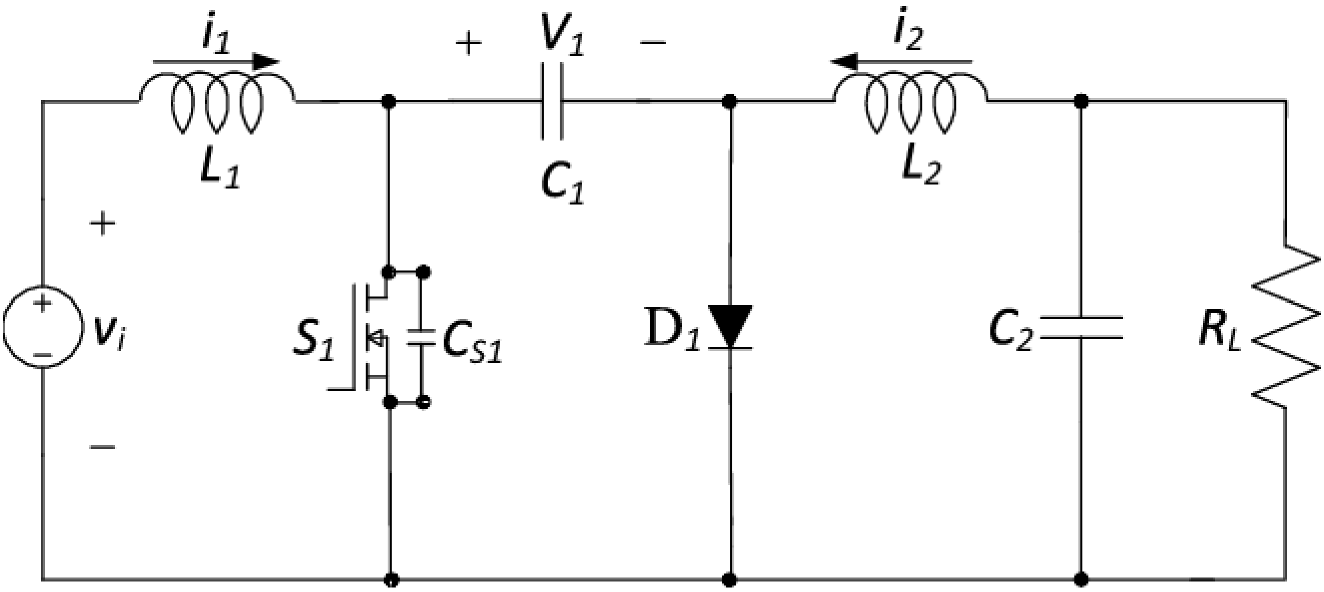


The MPPT section consists of 2 converters:

1- the MPPT converter
2- and the load regulation converter.

3.2.4.2 **The MPPT Converter.**

The MPPT converter is directly connected to PV panel, its function is to extract the maximum power from the panel and the Type of this converter is CUK converter.



Cuk converter circuit

<u>Parameter selection:</u>

V_{c1}=

V_0=

L_2=

I_0=

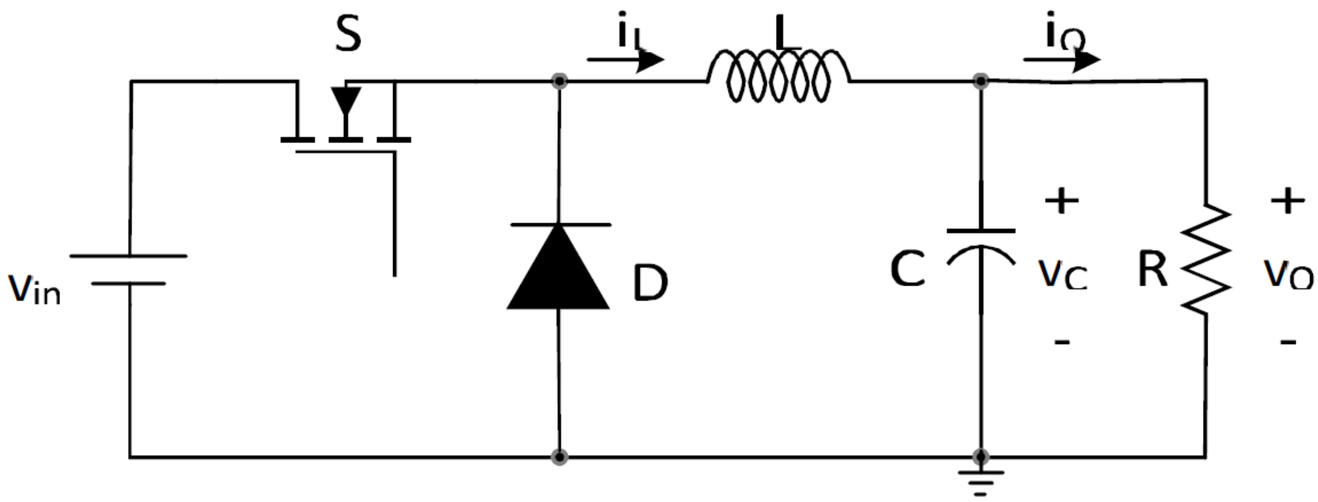
C_1=

ΔV_0=

3.2.4.3 The load regulation converter.

The regulation converter is directly connected to the load, its function is to control the output voltage or output current cause the output voltage of MPPT Converter is variable and depend on the irradiance and temperature. The type of this converter is BUCK.

- **Circuit diagram:**



Buck converter circuit

- **Parameter selection:**

$V_0 = D\,V_{in}$

L=

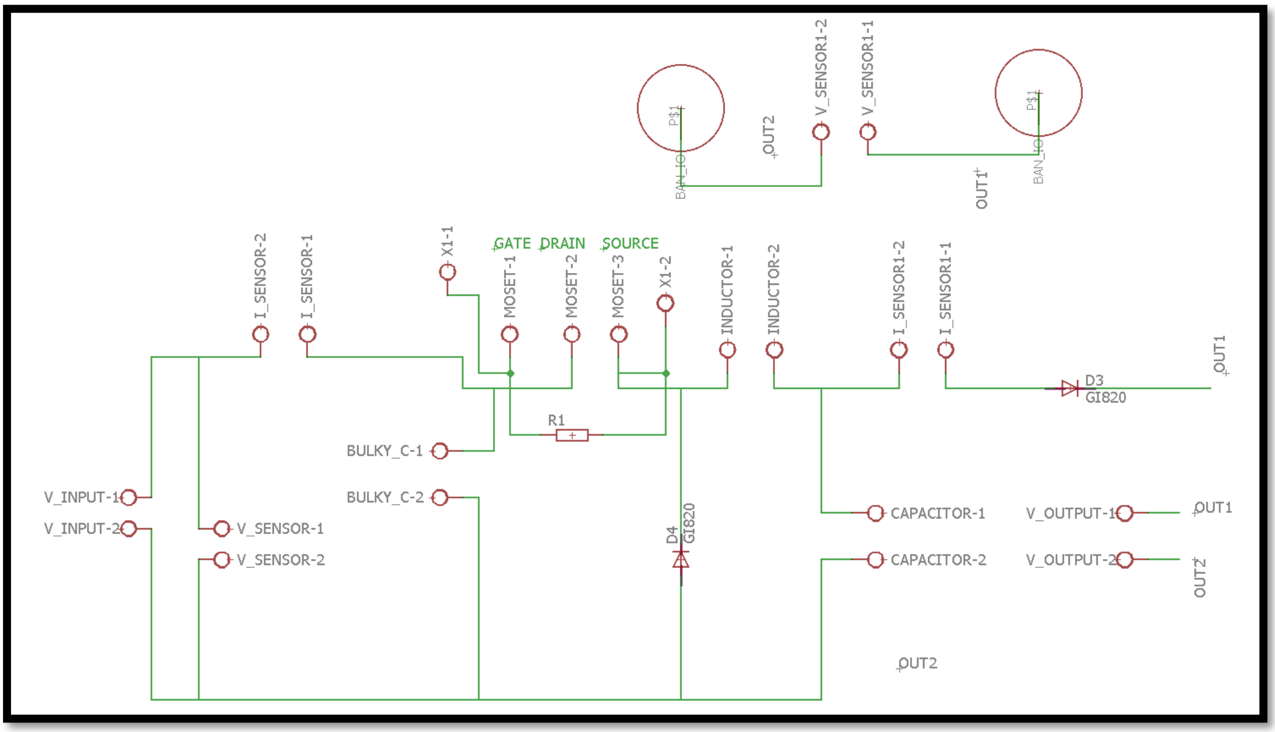
C=

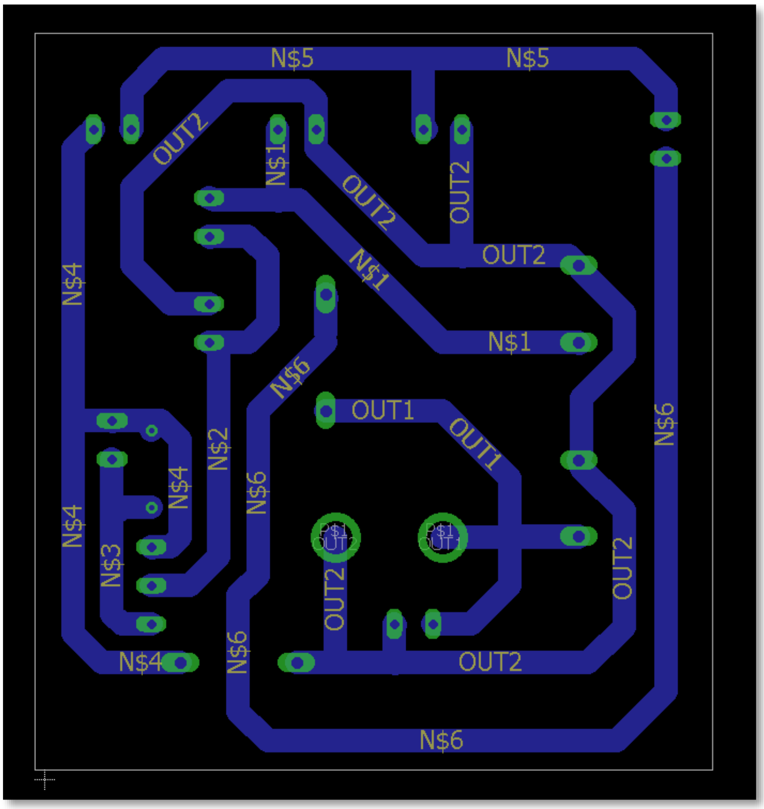
- **arduino Code:**

```
#include <PWM.h>
  int32_t freq=5000;
  int i=50;
  int pwmpin=9;
  float vin=0.0;
  float vout=0.0;
  float R1=31000.0;
  float R2=7500.0;
  int value=0.0;
void setup() {
    pinMode(A8,INPUT);
    Serial.begin(9600);
     pinMode(9,OUTPUT);
    InitTimersSafe();
    SetPinFrequencySafe(pwmpin,freq);
}
```

```
void loop() {
  value=analogRead(A8);
  vout=(value*5.0)/1042.0;
  vin=vout/(R2/(R1+R2));
  if(vin <12 && i<255 ){
    i=i+1;
  analogWrite(pwmpin,i);
  }
  if( vin>12 && i>0){
    i=i-1;
    analogWrite(pwmpin,i);
    }
    analogWrite(pwmpin,i);
    Serial.print(i);
  }
```

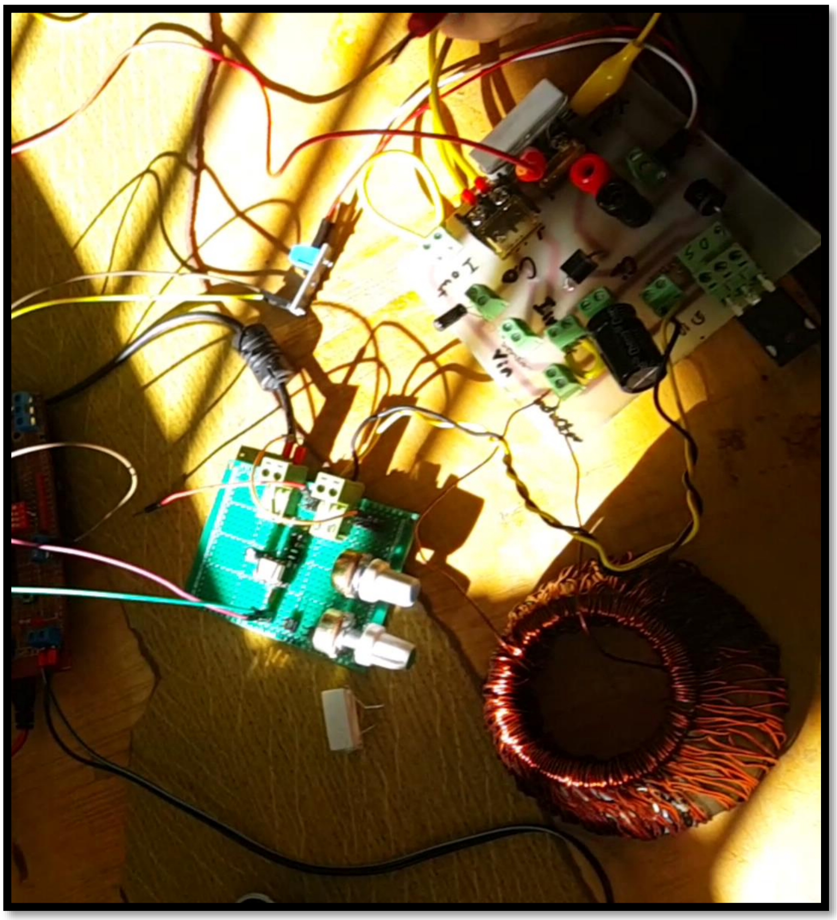
- **PCB design:**





N$5
N$5
OUT2
N$1
OUT2
OUT2
OUT2
N$1
N$1
N$4
N$6
OUT1
OUT1
N$2
N$4
N$6
N$6
N$4
N$3
OUT2
OUT2
N$4
N$6
OUT2
N$6

- **Hardware:**



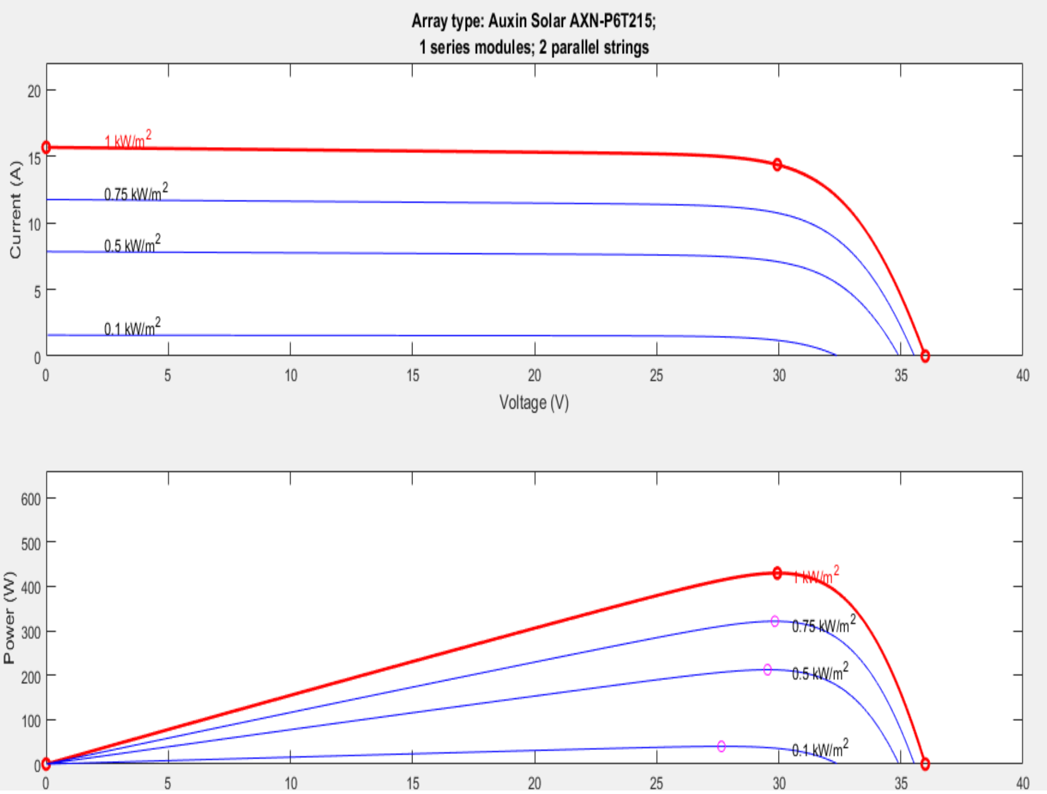
3.2.5 Simulink simulation of the MPPT section.

3.3.5.1 Simulation of the MPPT converter.

- **Array characteristics:**

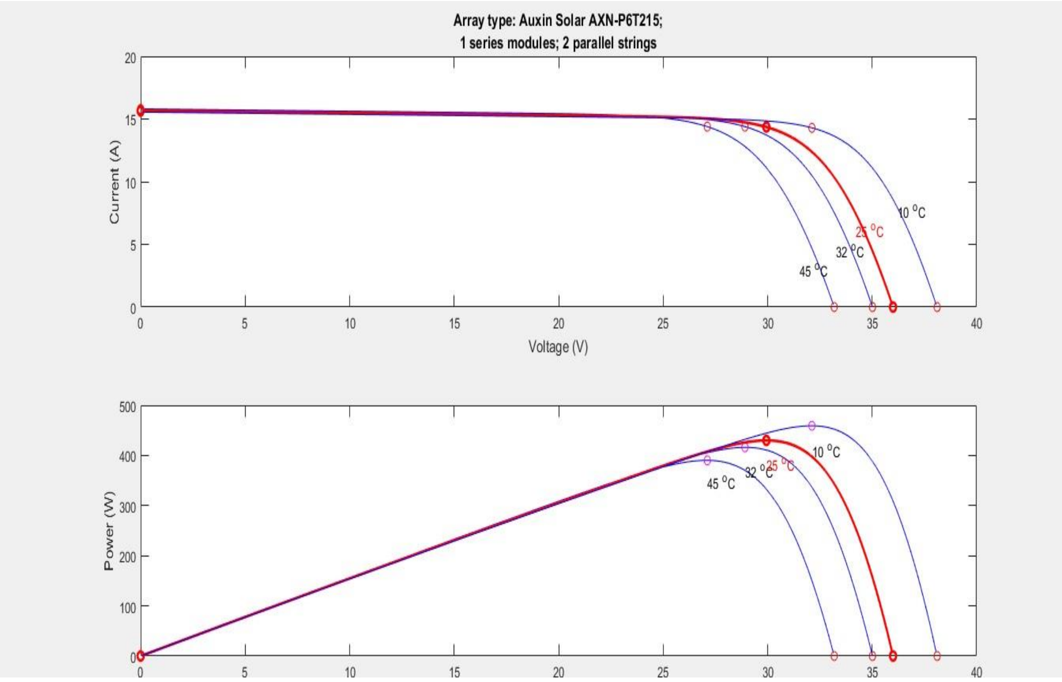
a- with variable irradiance:

as irradiance increases the MPPT increases.

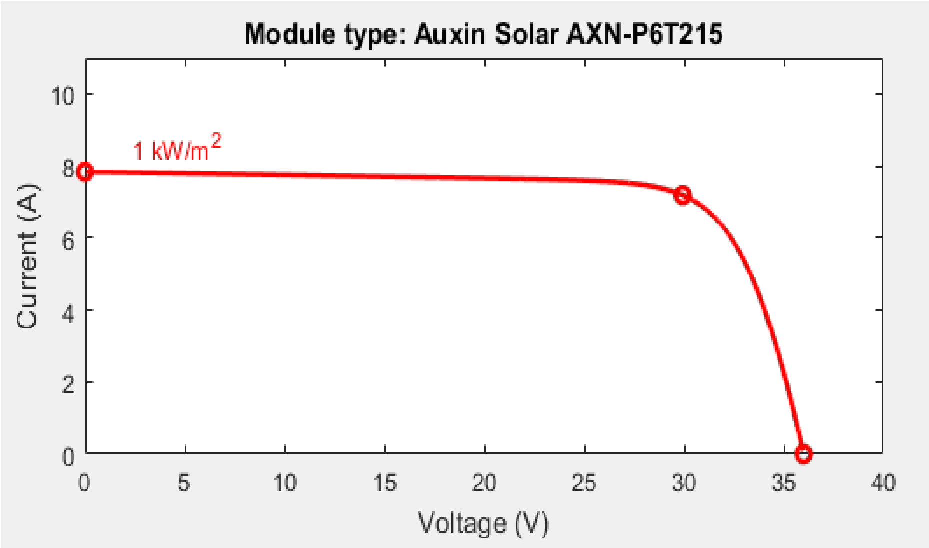


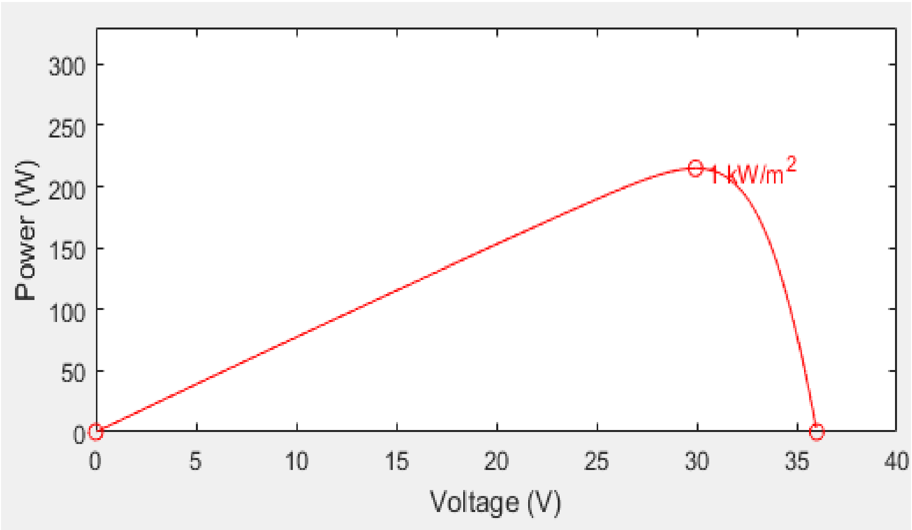
b- with variable temperature:

as temperature increases the MPPT decreases.

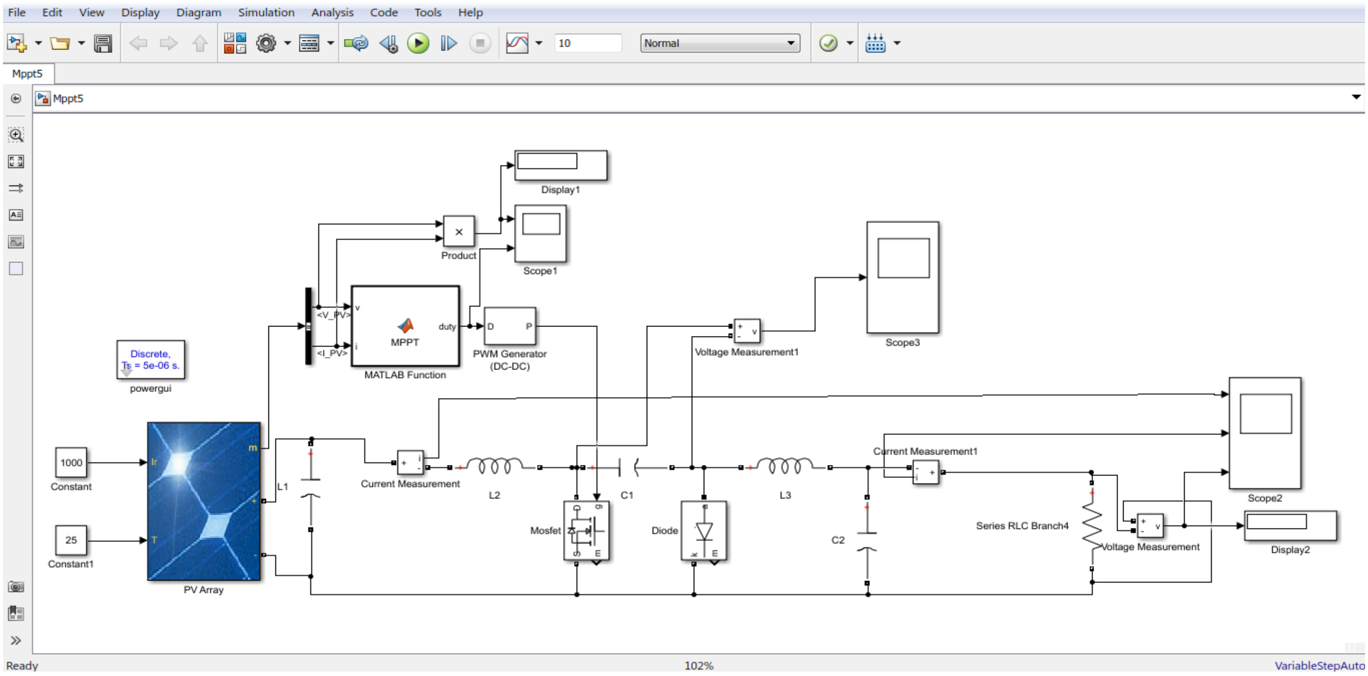


b- at standard test conditions:

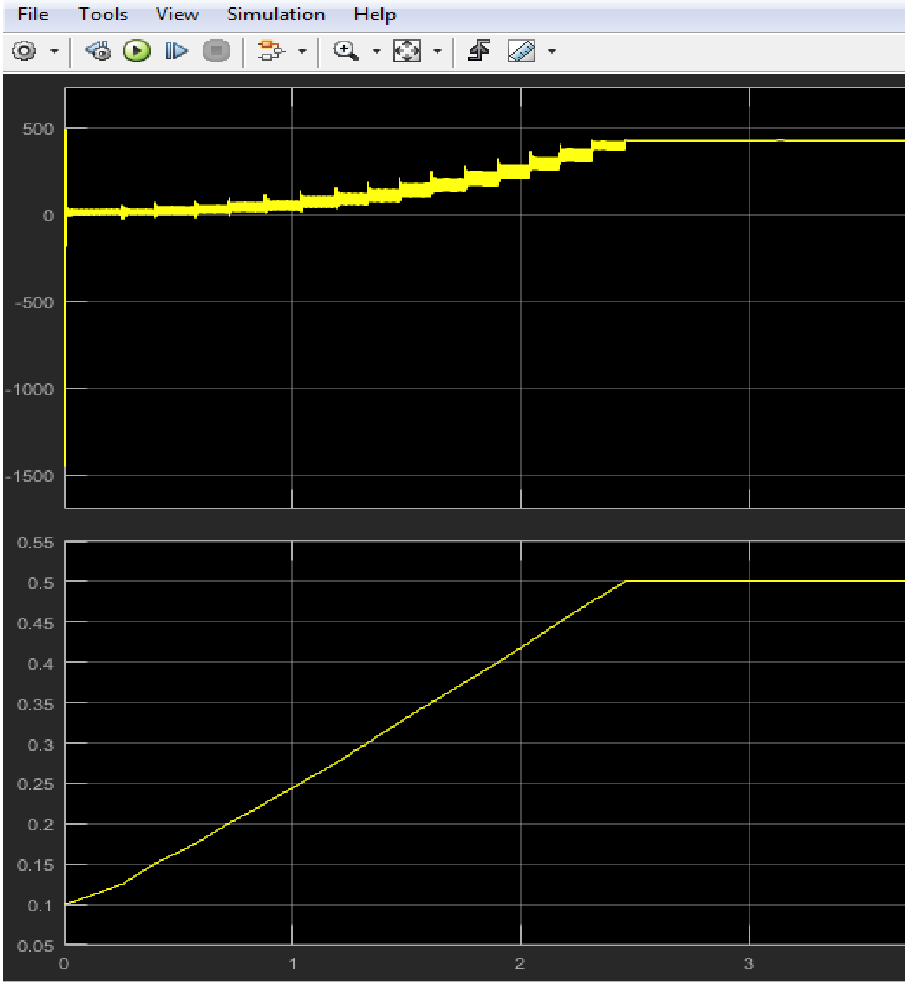




- <u>**Simulink model:**</u>



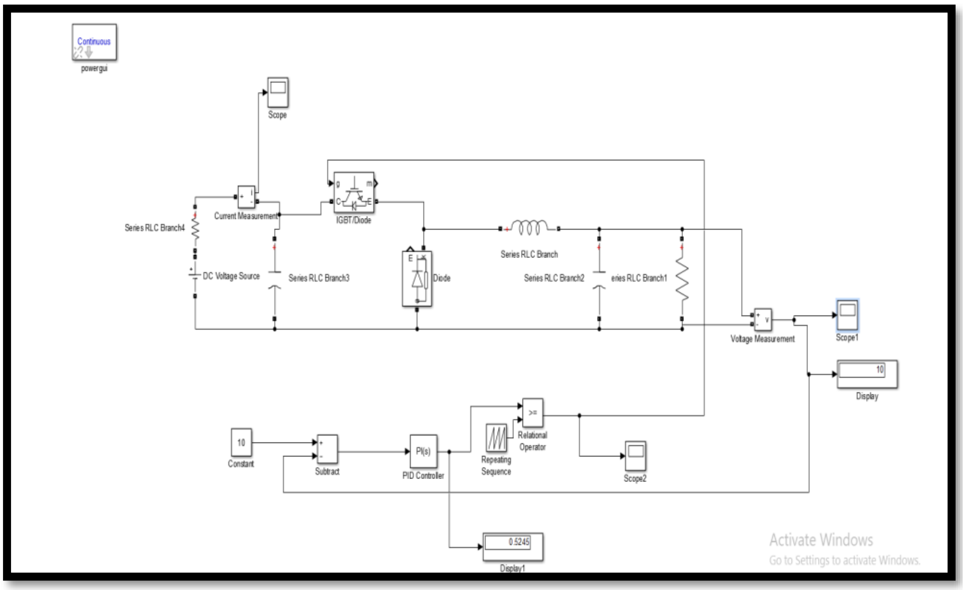
- <u>**Scope results:**</u>



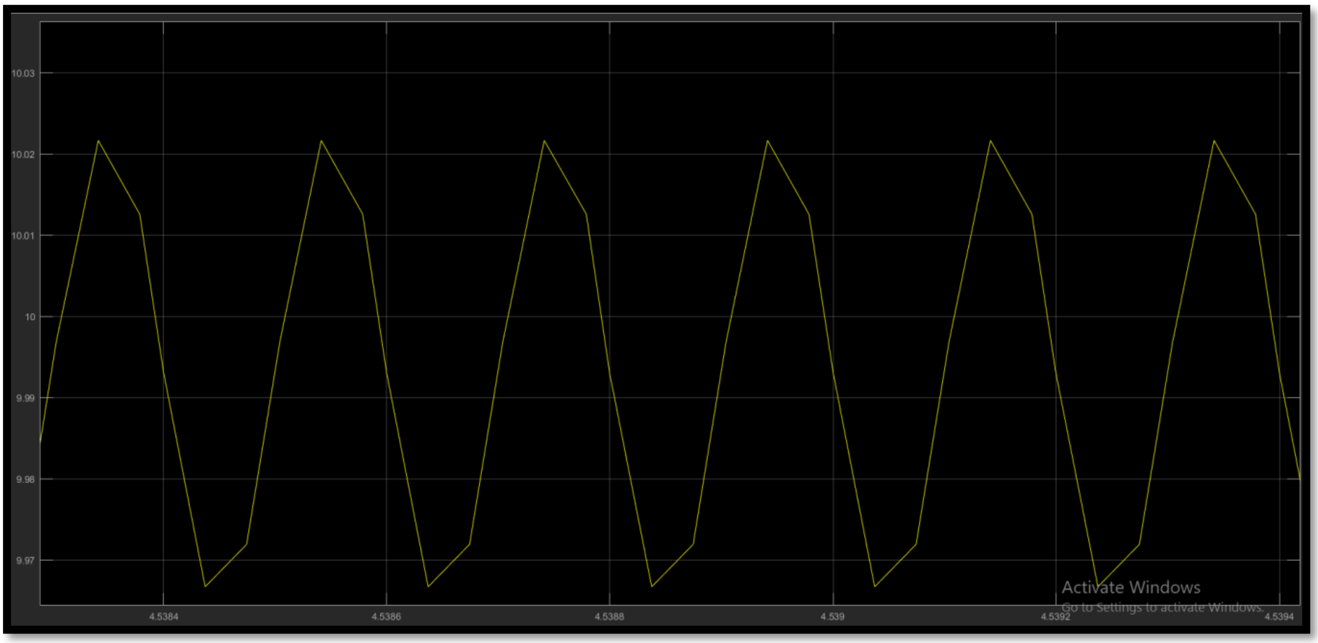
Note that after a few seconds **the power reaches the MPPT at around 400 watts**. This value is **the same as the peak of the power curve shown the array characteristics at 1000W/m² and 25°C.**

3.3.5.2 Simulation of the PWM converter.

- <u>**Simulink model:**</u>



- **Scope results:**



3.3 References.

1.	**Photovoltaic Design and Installation for Dummies**, by Ryan Mayfield.
2.	**Power Electronics: Converters, Applications, and Design 3rd Edition**, by NED MOHAN.

Chapter 4

Embedded system development and IOT.

4.1 The Embedded Control Section.

4.1.1 Introduction.

The word embedded implies that some entity is homogeneously integrated within a system. In the present-day context, an embedded system is **a hardware electronics arrangement within which a software is loaded in the memory element to drive the system to achieve its goal**. An embedded system is a realization of a definition of **some kind of automatic process guided by a set of rules**. **The hardware and their response to the real time working environment** are bonded together by these rules which are called **embedded software**.

The main functions of our system are **sensing and controlling**. Therefore, it relies on some **sensors** to **measure** different important quantities and **actuators** to **perform** the system tasks.

The embedded software development may have 3 stages as the case with our design or more. The **3 main stages** are:

1- **Embedded Driver Layer Development,**
2- **Embedded OS Development (RTOS Layer Development),**
3- **and Application Layer Development.**

4.1.2 Control system components.

4.1.2.1 Sensors.

Sensors and Embedded Systems generally work together to provide the most important control aspects:

- **detecting changes** in objects (devices or assets), the environment or both
- and **allowing for capture of relevant data for real-time or post-processing**.

They are the eyes of modern electronic devices utilized to implement automation in different practical fields. Sensors form the basic components of many systems, in which a process is controlled based on the signals sensed by the sensors.

Sensors are used to **frequently generate various signals as a response to various natural or artificial ambient factors.** These ambient factors may include temperature, light, pressure, sound, and motion. Logical changes include the presence or absence of an electronically traceable entity, location, or activity.

To allow our system to interact with surroundings, our control subsystem makes use of some sensors. These sensors are:

- Ultrasonic Sensors,
- Temperature Sensors,

- Voltage Sensors,
- and Current Sensors,

These sensors **send real-time data to the microcontroller with minimal delay** to assure **efficiency** and **fast respond** to any variance that may occur on the system.

We used **a different controller (ARDUINO board)** to test the sensors **with a simple code**. Then, after the other 2 design stages were finished the sensors code was written in **the main controller (TIVA board)** code **based on the developed drivers and the RTOS tasks**.

4.1.2.1 Main Control Unit.

The used control unit is **TM4C123GH6PM Microcontroller (TIVA C)** which a wide range of features. It targets performance and flexibility and is a good choice for cost-conscious applications requiring **significant control processing and connectivity** capabilities such as:

- Low power, hand-held smart devices.
- Gaming equipment.
- Home and commercial site monitoring and control.
- Motion control.
- Medical instrumentation.
- Test and measurement equipment.
- Factory automation.
- Fire and security.
- Smart Energy/Smart Grid solutions.
- Intelligent lighting control.
- Transportation.

The ARM Cortex-M processor provides the core for a high-performance, low-cost platform that meets the needs of minimal memory implementation, reduced pin count, and low power consumption, while delivering outstanding computational performance and exceptional system response to interrupts. The following table contains the features of the TM4C123GH6PM microcontroller:

Feature	Description
Core	ARM Cortex-M4F processor core
Performance	80-MHz operation
Flash	256 KB single-cycle Flash memory
System SRAM	32 KB single-cycle SRAM
EEPROM	2KB of EEPROM
Universal Asynchronous Receivers/Transmitter (UART)	Eight UARTs
Synchronous Serial Interface (SSI)	Four SSI modules
Inter-Integrated Circuit (I2C)	Four I2C modules with four transmission speeds including high-speed mode

Controller Area Network (CAN)	Two CAN 2.0 A/B controllers
Universal Serial Bus (USB)	USB 2.0 OTG/Host/Device
Micro Direct Memory Access (µDMA)	ARM® PrimeCell® 32-channel configurable µDMA controller
General-Purpose Timer (GPTM)	Six 16/32-bit GPTM blocks and six 32/64-bit Wide GPTM blocks
Watchdog Timer (WDT)	Two watchdog timers
Hibernation Module (HIB)	Low-power battery-backed Hibernation module
General-Purpose Input/Output (GPIO)	Six physical GPIO blocks
Pulse Width Modulator (PWM)	Two PWM modules, each with four PWM generator blocks and a control block, for a total of 16 PWM outputs
Analog-to-Digital Converter (ADC)	Two 12-bit ADC modules, each with a maximum sample rate of one million samples/second
Analog Comparator Controller	Two independent integrated analog comparators
Digital Comparator	16 digital comparators

4.1.3 Functions of the main controller

Function	**Description**
1. DATA ACQUISITION.	The microcontroller gathers the signals from the sensors connected to it. These signals contain information about the following: 1. Main tank water level measured by Ultrasonic Sensor. 2. Storage tank water level measured by Ultrasonic Sensor. 3. Filter Tank water level measured by Ultrasonic Sensor. 4. Main tank water temperature measured by Temperature Sensor. 5. Hardware board temperature measured by Temperature Sensor. 6. Pump current using Current Sensor.
2. DATA PROCESSING.	Data collected by the controller from the sensors is processed into useful information. This information is necessary to decide when to take control actions. The software defines maximum and minimum operating values for the water level within which the system shall operate in a normal condition. On the other hand, if one of the measured quantities is higher than the maximum value or lower than the minimum value, the system is said to be in an abnormal condition in which the microcontroller should take a predefined

	control action to assure the system is set to its normal condition as soon as possible.
3. SYSTEM CONTROL.	The water filtration cycle consists of the three stages: 1- the first stage discharges the **water from the main tank to the filter tank** until it reaches its maximum value **(1 VALVE),** 2- the second stage **compensates the water loss in the main tank by filling it with water from storage tank** until it reaches the maximum value **(PUMP and 2 VALVES),** 3- and the third cycle allows water from the filter tank to the storage tank **(PUMP and 2 VALVES)**. The main control unit controls the pump and valves to achieve the above control sequence and signals indication signals to the **main control panel.** The whole cycle can be **automatically** controlled and repeated it until the water pureness becomes suitable. It can also be **manually** controlled stage by stage or in single cycle mode or even stopped at any stage.
4. COMMUNICATION.	The microcontroller doesn't only monitor and control the system but also **sends the gathered data from the sensors to the end user through the gateway of the IoT**. Therefore, the cloud is informed him with the ongoing status of the system. Moreover, **it allows the user to control some operations in the system** such as filling and discharging the water in the tank, or entering sleep mode to conserve power.
5. POWER SAVING.	The developed software aims to save the power drawn from the microcontroller and the hardware circuits as much as possible by a means of power management plan implemented by the software.
6. MULTI-TASKING.	In addition to the low power consumption, the system is managed by a **self-developed, multi-tasking OS software** to manage the hardware resources which in turn increases the efficiency and execution speed of the code to assure a fast response system with minimal delay between the different tasks.

4.1.4 Embedded Driver Development.

The main objective of this design stage is implicating the hardware complexities so that the other application layer doesn't have to deal with such complexities. This stage includes:

- Developing **a ".h" controller specific header file** that has all the register details of the controller. The board data sheet is used in this stage to get the register details of each peripheral of the microcontroller.
- Developing **one ".h" header file for each peripheral** of the micro controller that contains: **general macros and prototypes of the functions feathered by the driver**.
- Developing **one ".c" source file for each peripheral** that contains **the definitions of the functions declared in the peripheral header file**.

The other application layer can make use of the developed drivers functions to **touch the different peripherals of the microcontroller without having to refer to hardware complexities.**

4.1.5 RTOS Layer Development.

An Operating System is a piece of software that manages the microcontroller resources (hardware), and provides a platform on which a user can execute tasks in a convenient and efficient manner. The coordination of the hardware must be appropriate to ensure the correct working of the system and to prevent user tasks from interfering with the proper working of the system. **The OS acts as a communication bridge (interface) between the user and microcontroller hardware.**

Responsibilities of the OS include:

- **Hiding the complexities of hardware from the user.**
- **Effective management of the hardware's resources** which include the processors, memory, data storage, communication modules, and I/O devices.
- **Handling "interrupts"** generated by the I/O controllers.
- **Sharing of I/O between many programs using the CPU.**

The design of our software is a **multi-tasking environment rather than a simple sequential code** which would result in a delay of execution. Therefore, the overall functionality of the system is divided into smaller functionalities which in an OS environment called **Tasks**.

A certain process may need a certain input from a switch or a sensor and this input may take some time before received, with no multithreaded environment, the system would unnecessarily have to wait doing nothing else until the input is received which would affect the remaining functions of the system. Instead a better approach would be to **check periodically for the desired input while executing other system functions in that time**. This can be done using multitasking environment.

Multitasking in an interactive application can allow a program to continue running even if a part of it is blocked or is performing a lengthy operation, thereby increasing system responsiveness.

Multitasking Software Design Advantages

1. **Responsiveness:** Program responsiveness allows a program to run without freezing even if part of it is blocked.
2. **Resource Sharing:** All the tasks of a process shares its resources such as memory, data, I/O channel, communication module.
3. **Improved throughput**: Many concurrent computing operations and I/O requests within a single process.
4. **Minimized system resource usage:** Tasks impose minimal impact on system resources. Tasks require less overhead to create, maintain, and manage than a traditional process.
5. **Program structure simplification**: Tasks can be used to simplify the structure of complex applications. Simple routines can be written for each activity, making complex programs easier to design and code, and more adaptive to a wide variation in user demands.
6. **Better communication:** Task synchronization functions can be used to provide enhanced process-to-process communication.

The OS decides the order in which tasks have access to the processor according to its priority in the system and for some cases according for how long it has been waiting for a chance to gain access to the processor. The OS also decides how much processing time each task has before giving up the processor for another task. Because the switching between tasks may happen hundreds of times per second, or more, **it appears to the user that the processor executes several tasks in parallel**. This function of OS is called **Process Scheduling**.

In multi-tasking programming, **each task has its own memory with a specific size**. **The OS decides the order in which tasks are granted access to its own memory stack, and for how long. It allocates the memory to a task when the tasks request it and deallocates the memory when the task has terminated or is performing an I/O operation.**

The Operating System is responsible for execution of all types of tasks whether it be user tasks or system tasks. It utilizes various resources available for the efficient running of all types of functionalities, and manages the data flow between different tasks to provide enhanced process-to-process communication. The Operating System also ensures the proper use of all the resources available by deciding which resource to be used by whom and for how much time, this means that in a shared resource system, **if a task gains access to a shared resource such as UART or I/O channel, no other task can gain access to that resource until the current one releases it.** This called **Mutual Exclusion.**

Our project software is divided into three types of tasks; **Measurement Tasks, Control Tasks, and Communication Tasks**. These tasks are as follows:

1. Main Tank Water Level Task.
2. Storage Tank Water Level Task.
3. Filter Tank Water Level Task.
4. Main Tank Water Temperature Task.
5. Board Temperature Task.
6. Pump Current Task.
7. Switches Inputs Task.
8. Automatic Mode Task.
9. Single Cycle Task.
10. Stage 1 ON Task.
11. Stage 2 ON Task.
12. Stage 3 ON Task.
13. Stage 1 OFF Task.
14. Stage 2 OFF Task.
15. Stage 3 OFF Task.
16. IoT Gateway Communication Task
17. Charge Controller Communication Task

4.1.6 Application Layer Development.

The tasks mentioned before are handled in the application layer development stage. By handling we mean implementing the tasks to do their function. Our project software has three types of tasks **Measurement Tasks, Control Tasks, and Communication Tasks**.

All **measurements tasks** have the same sequence which is **receiving the sensor signal, processing it** to make sure it's within the safe limits, **then finally sending the data to the Communication Task which then sends the data to the IoT gateway.** In case the system isn't operating within the predefined safe limits, the task raises a flag to inform the OS with that, **after that the OS gives the proper control task access to the processor and its memory to start a corrective action.**

Control tasks are responsible for **generating the proper output signals to operate the actuator responsible for operating a certain stage.** The output signals are maintained until the quantity level reaches the safe predefined value once more, then the task resets theses output signals to stop the actuator.

The third type of tasks in the **communication tasks**. **IoT Communication Task's** job is to gather the **system data** from the measurement tasks and send them to the IoT gateway. It's also responsible for **receiving the commands** sent by the user through the IoT gateway, processing them, and performing the requested action. **Charge Controller Communication Task** is responsible for gathering the voltage and current measurements for both the solar panel and the battery from the charge controller and sending them to the IoT gateway.

4.1.7 Power Management.

Many embedded system products require low power microcontrollers, especially portable products that run on batteries. In addition, low power characteristics can benefit product designs in many ways, including:

1. Smaller battery size (smaller product size and lower cost) or longer battery life.
2. Lower electromagnetic interference (EMI), which allows better wireless communication quality.
3. Simpler power supply design, avoiding heat dissipation issues.
4. In some cases, it even allows the system to be powered using alternate energy sources (solar panel, energy harvesting from the environment).

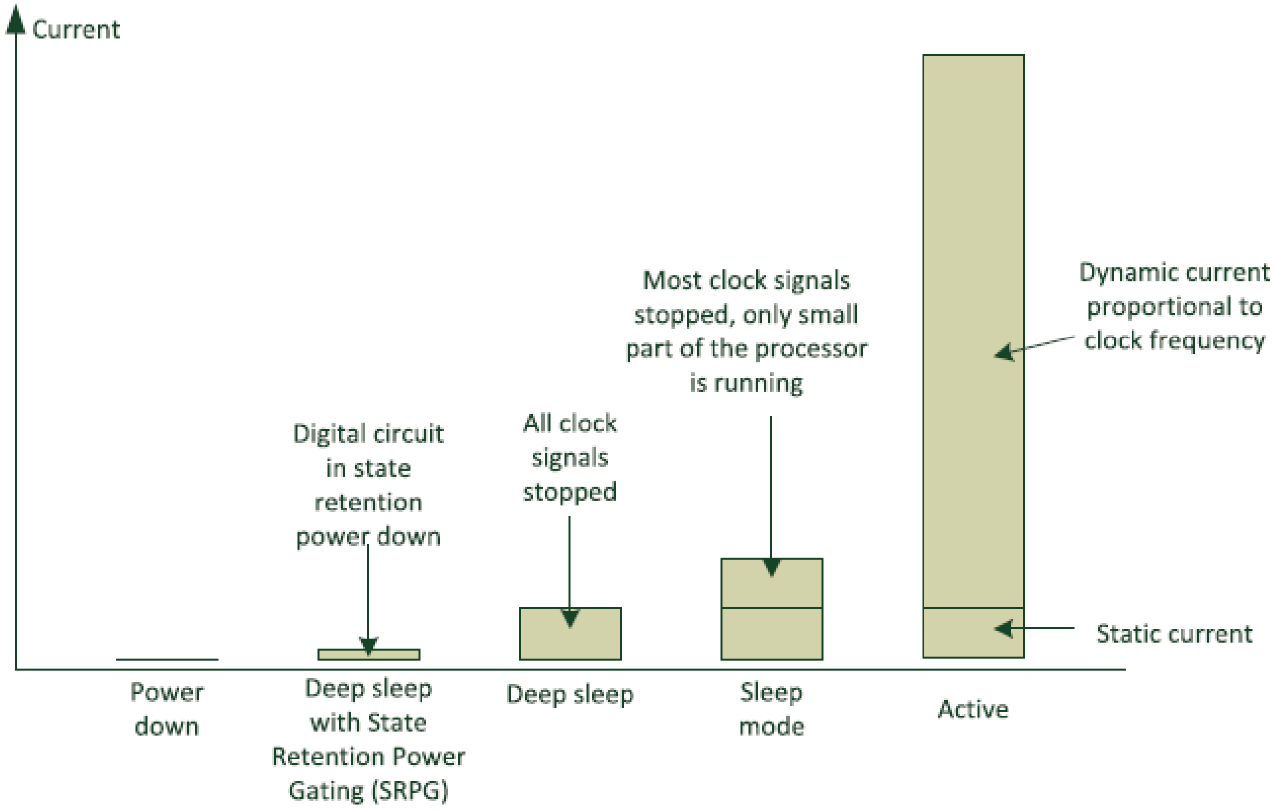
Generally, in some battery powered products energy efficiency is the most important factor, while in some industrial control applications the wake-up latency can be critical. In our case the energy efficiency is what matters **because of the lack of a grid-connected power supply and the dependence on solar energy and batteries.** The data processing request is periodic and has a constant duration, and the data processing latency is not an issue hence. Therefore, in order to reduce the power consumption, we're running the system **at 16 MHZ clock speed** in run mode, and using **the deep sleep mode** as the low power mode to effectively minimize the power consumption.

<u>Run Mode</u>

In Run mode, the microcontroller actively executes code, and provides normal operation of the processor and all of the peripherals. Run mode is the normal mode of the microcontroller.

<u>Deep Sleep Mode</u>

In Deep-Sleep mode, the clock frequency of the active peripherals may change in addition to the processor clock being stopped, but the processor and the memory subsystem are not clocked and therefore no longer execute code. In case of a system disturbance, the microcontroller wakes up very quickly from the deep sleep mode and keeps functioning as normal. This mode is activated upon user request.



4.1.8 References.

1.	**Definitive Guide to ARM(r) Cortex(r)-M3 and Cortex(r)-M4 Processors.**
2.	**Tiva C EK-TM4C123GXL Datasheet.**

4.2 The IOT section.

4.2.1 Introduction.

The internet of things, or IOT, is a **system of interrelated computing devices**, **mechanical and digital machines, objects, animals or people that are provided with**:

- **unique identifiers (UIDs)**
- and **the ability to transfer data over a network** without requiring human-to-human or human-to-computer interaction.

A thing in the internet of things **can take many forms**. It can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object. **Generally, a thing is any object that can be assigned an Internet Protocol (IP) address and is able to transfer data over a network.**

Increasingly, organizations in a variety of industries are using IoT to operate more efficiently, better understand customers to deliver enhanced customer service, improve decision-making and increase the value of the business. In the next section we mention briefly the benefits off implementing an IOT system.

4.2.2 Benefits of IOT.

Benefits to individuals:

- It helps individuals take full control of their lives and properties even when they are not near them **utilizing the growing home automation devices with the IOT system**. Home automation helps the owner to monitor and control his house even when he is away from it.
- It can be used to control the utilities in a city in a more efficient way. The trend of smart cities where every thing is integrated to an IOT platform has seen a lot of growth in the past few years

Benefits to companies and organizations:

The internet of things offers several benefits to organizations. Some benefits are **industry-specific**, and some are **applicable across multiple orginizations**. Some of the common benefits of IoT enable businesses to:

- monitor their overall business processes,
- improve the customer experience (CX),
- save time and money,
- enhance employee productivity,
- rethink the ways they approach their businesses by giving them the tools to improve their business strategies,
- and make better business decisions, and generate more revenue.

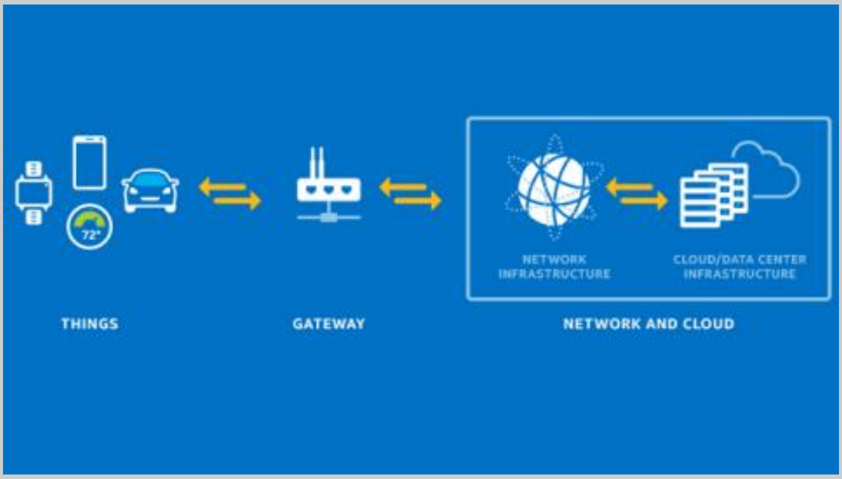
Conclusion:

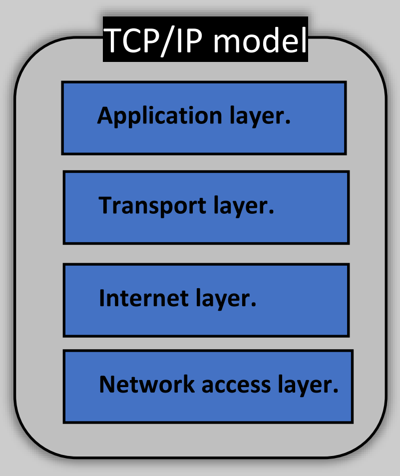
IOT provides many benefits that can be extended to every aspect of our lives. It transforms a regular house or apartment to a smart home, a regular organization to a smart and more efficient organization and a city into a smart city. Hence, **as the IOT field experiences more growth our lives continue to become easier.**

As IoT becomes an essential aspect of any modern project, it's implemented in our project to **provide continuous supervision, data visualization and status feedback of the unit** for further enhancements and continuous developments through analyzing the gathered data, hence **improving system performance and preventing unexpected failure in any part of the system**

4.2.4 The key components of an IOT system.

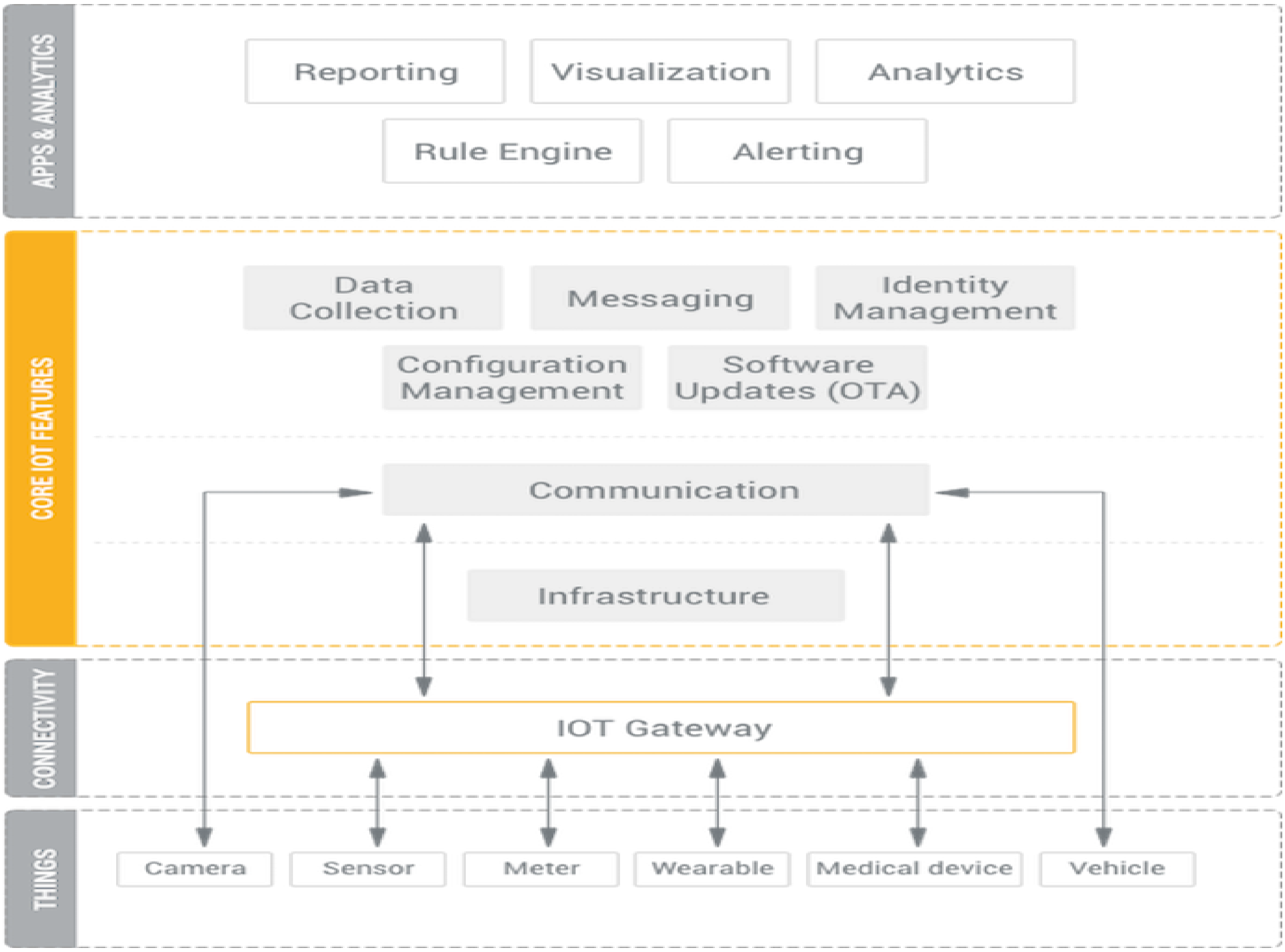
The table below lists the basic components of an IOT system and some of the key points about each component.

COMPONENT	KEY POINTS
1- Gateway:	• Gateway enables **easy management of data traffic flow**. It also translates the network protocols and makes sure that the devices and sensors are connected properly. • It can also work to preprocess the data from sensors and send them off to next level if it is configured accordingly. • It is essential to configure it properly to **utilize the TCP/IP model to communicate with the cloud platform server.** • It also gives **proper encryption** with the network flow and data transmission. **The data flowing is therefore protected by using the latest encryption techniques**. • Hence, **it can be can assume an extra layer between the cloud and physical devices that filter away the attack and illegal network access.** 
2- Analytics:	• The analog data of devices and sensors are converted into a format that is easy to read and analyze. This is all possible due to the IoT ecosystem that manages and helps in improving the system. • The most important function of IoT technology is that it supports **real-time analysis** that **easily observes the irregularities and prevents any loss or scam**. Preventing the malicious things to attack the smart devices will not only give you a sense of security but also it will save all the data from being used for illegal purposes.

	• The big companies collect the data in bulk and analyze it efficiently. The collected data **presents a great help in both troubleshooting and planning system future improvements, resulting in a more accurate decision making.**
3- Cloud:	• The cloud basically combines many devices, gateways, protocols, devices and a data store that can be analyzed efficiently. • It is also a **host to the user interface providing many useful features depending on the IOT platform selected.**
4- User interface:	• This is another factor on which IoT ecosystem depends immensely. • It provides a visible and physical part that can be easily accessed by the user. • It is important for the developer to create **a user-friendly interface** that could be accessed without putting any extra efforts in it and that can help in easy interaction. • The user interface can take the for of a mobile app or a website. However**, in most cases IOT platforms provide dashboard as an editable user interface with many predeveloped supported templates.**
5- communication standard protocols:	• The network model used right now is the **TCP/IP model** which is a 4-layer model. These 4 layers are (from lowest to highest):  **1- <u>Network access layer:</u>** The gateway communicates through this layer with connected physical devices and sensors, providing network access for such devices. Most new sensors use topologies networks like LORAWAN, Wi-Fi, and Bluetooth makes it easy for them to stay connected. **2- <u>Internet layer:</u>** This layer is concerned with the IP and the ICMP protocols. IP helps ensuring that the data ends where it is supposed to end. Whereas the ICMP is a protocol used to support the IP protocol for error detection. **3- <u>Transport layer:</u>** This layer is concerned with either the TCP or UDP protocols. The TCP protocol is used when loss of part of the data is not acceptable. The UDP protocol is utilized when we care more about how fast a the data is transported. Since we are sending important data, the TCP protocol is used. **4- <u>Application layer:</u>** This layer is concerned with application layer protocols like HTTP and MQTT. Most webpages today use the HTTPS protocol together with CSS to make for a very stable, secure, and stylish user interface. However, **most IOT applications use the MQTT protocol** which is a simple messaging application layer protocol that utilizes the **PUB/SUB model.**

4.2.5 What is an IOT platform.

An IoT platform is a **multi-layer technology** that enables straightforward provisioning, management, and automation of connected devices within the Internet of Things universe. It basically connects your hardware, however diverse, to the cloud by using flexible connectivity options, enterprise-grade security mechanisms, and broad data processing powers. For developers, an IoT platform provides a set of ready-to-use features that greatly speed up development of applications for connected devices as well as take care of scalability and cross-device compatibility. The structure and features of an IOT platform are shown in the figure below.

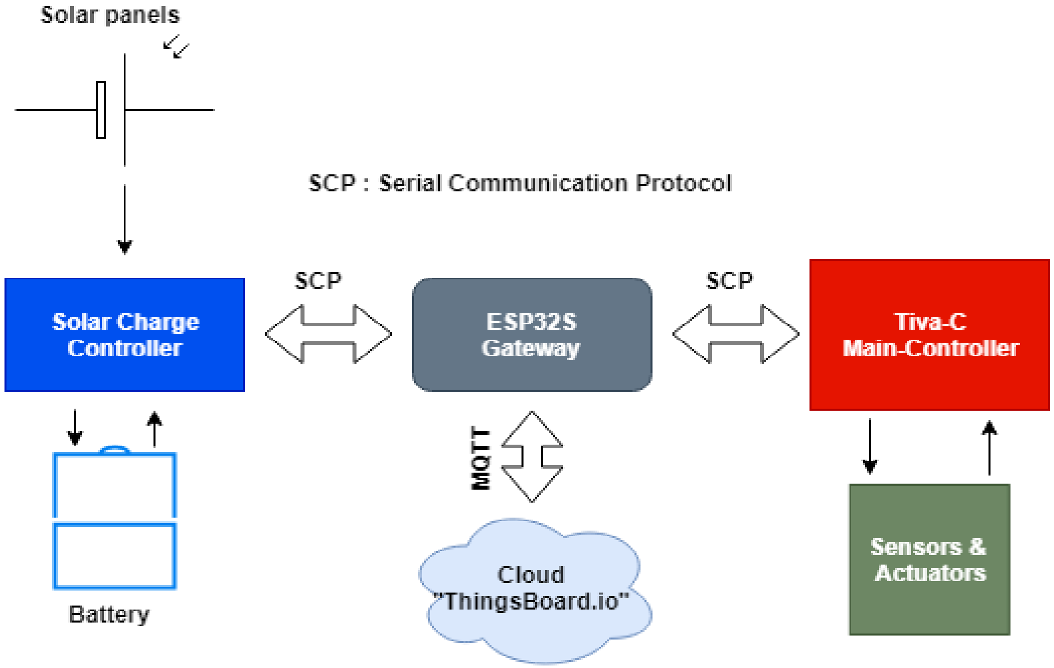


Therefore, it can be concluded that **the IOT platform acts as a middleware** between **the HARDWARE and the application layer of the system.**

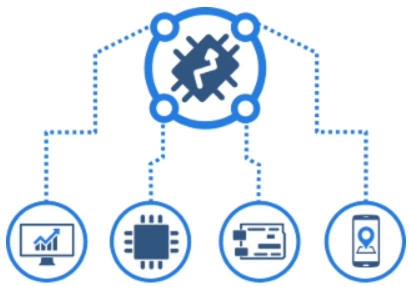
4.2.6 Implementation of the IOT section.

4.2.6.1 Overview of the IOT setup.

- **ESP32-WROOM-32** was chosen as a **GATEWAY** for the system. It is a powerful, generic Wi-Fi, BT, BLE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks.
- THINGSBOARD.IO was selected as the
- **The system has 2 controllers:**
    - **MPPT controller: Arduino board.**
    - **Main controller: TIVA development board.**
- The ESP GATEWAY controller communicates with:
    - the cloud using the MQTT application layer PROTOCOL,
    - and the 2 controllers of the system using a serial communication protocol such as SPI and UART.
- **The system sensors are connected to the main controller TIVA board.** Each sensor has a specified serial communication protocol like SPI, UART, I2C and onewire.
- An overview of the control and IOT setup is shown in the figure below.



4.2.6.2 Overview of THINGSBOARDS cloud platform.



- It is **an open-source IoT platform** for data collection, processing, visualization, and device management.
- It enables device connectivity via industry standard IoT protocols - MQTT, CoAP and HTTP and supports both cloud and on-premises deployments.
- ThingsBoard combines scalability, fault-tolerance and improved performance to provide accurate data.

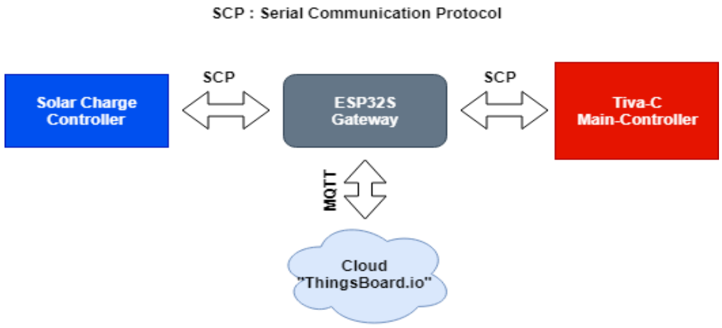
- **Main Features:**
  - **Provision and management of devices and assets:**
    Provision, monitoring and control of all the IoT entities in secure way using rich server-side APIs. Define relations between your devices, assets, customers or any other entities.

  - **Collection and Visualization of data:**
    Collecting and storing telemetry data in scalable and fault-tolerant way. The **collected data can be visualized using built-in or custom widgets together with a flexible dashboard.** Dashboards can be shared with the user of the system.

  - Process and React.
  - Micro services.

4.2.6.3 How data flows in the whole control and IOT section.

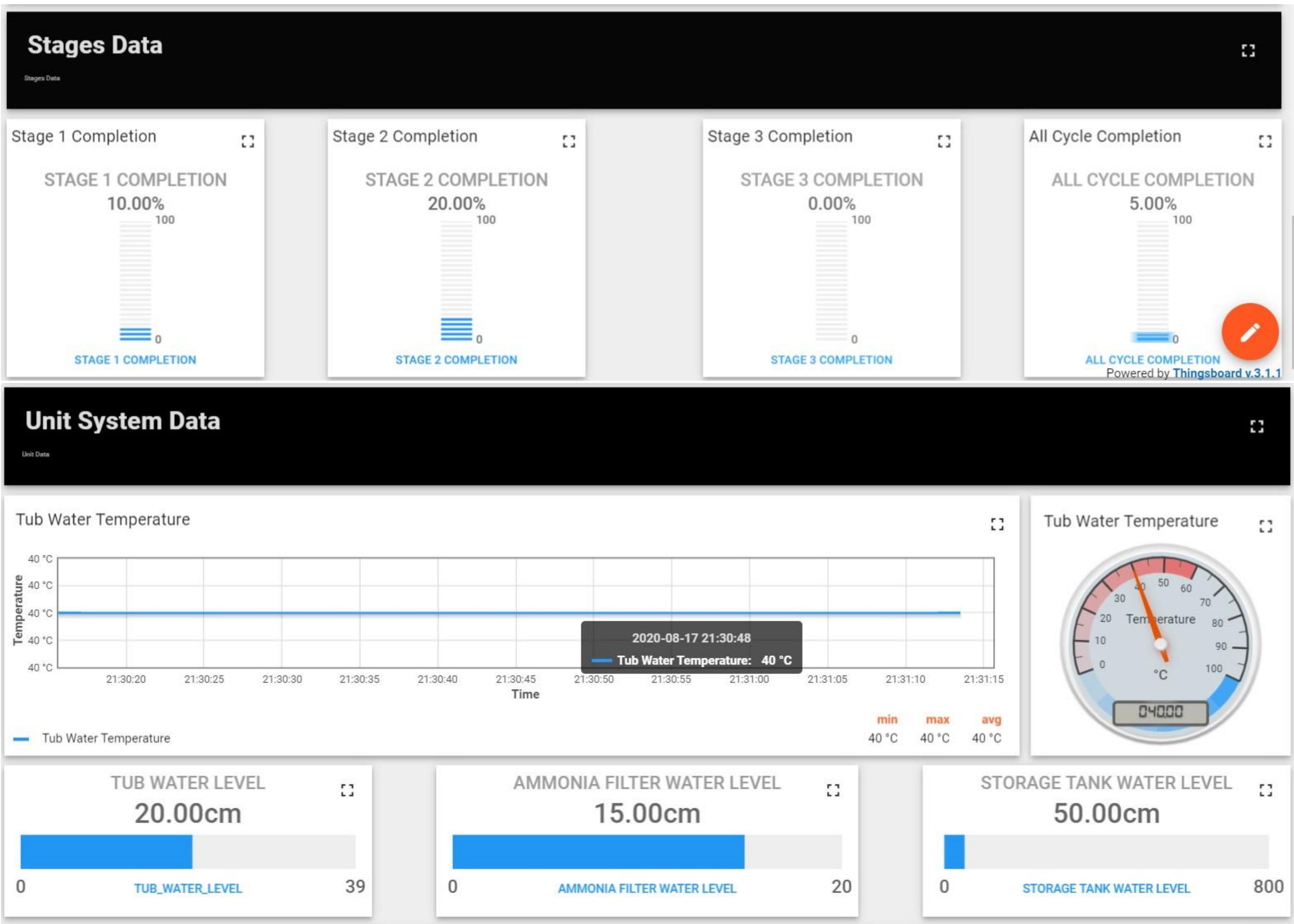
- Using Esp-32s Wi-Fi library, Wi-Fi chip will be enabled and initialized to be connect to Wi-Fi network. Wi-Fi network name “SSID” and password must be entered to the system to connect to Wi-Fi network.

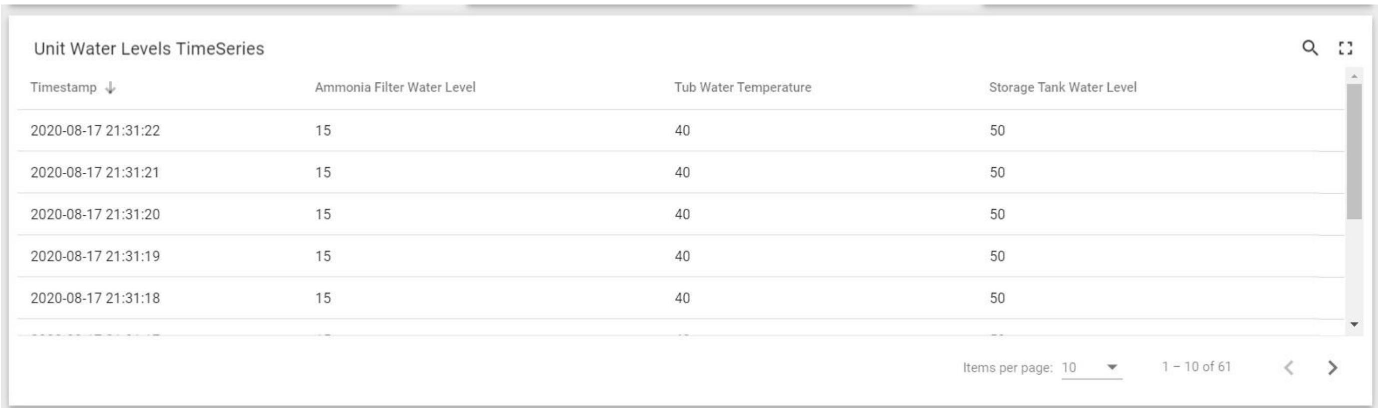


- After connecting to Wi-Fi network:
  - **The THINGSBOARD library is used to establish a connection between IoT platform server side and Esp-32s board.**
  - ThingsBoard library consists of **ArduinoHttpClient, PubsubClient, ArduinoJson libraries.**
  - **ArduinoHttpClient and PubsubClient libraries** are used to establish the connection between Esp-32s and cloud network.
  - **ArduinoJson library** is used to **construct telemetry messages** that contain the required data to be published.
  - ThingsBoard library uses the **MQTT protocol** to establish a connection with cloud network to publish data in the form of telemetry messages. Esp32s becomes MQTT client “Gateway”, that handles messages requests between Cloud “MQTT broker” and system.
- As Esp-32s has several integrated interfacing ports, Serial communication protocols such as : SPI, I2C, UART, etc. will be used to collect data from Tiva-C and solar charge controller to Esp-32s , then publish data to cloud as shown in figure.
- The TIVA-C microcontroller board will handle the system process, and send system parameters and operation conditions to Esp-32s. Solar charge controller will handle unit power management and send system parameters and operation condition to Esp-32s, then when updated data is received by Esp-32s from any controller data, a request will be send to cloud to publish data, and messages will be send to cloud containing the required data to published using MQTT network protocol.

4.2.6.4 **Dashboard layout.**

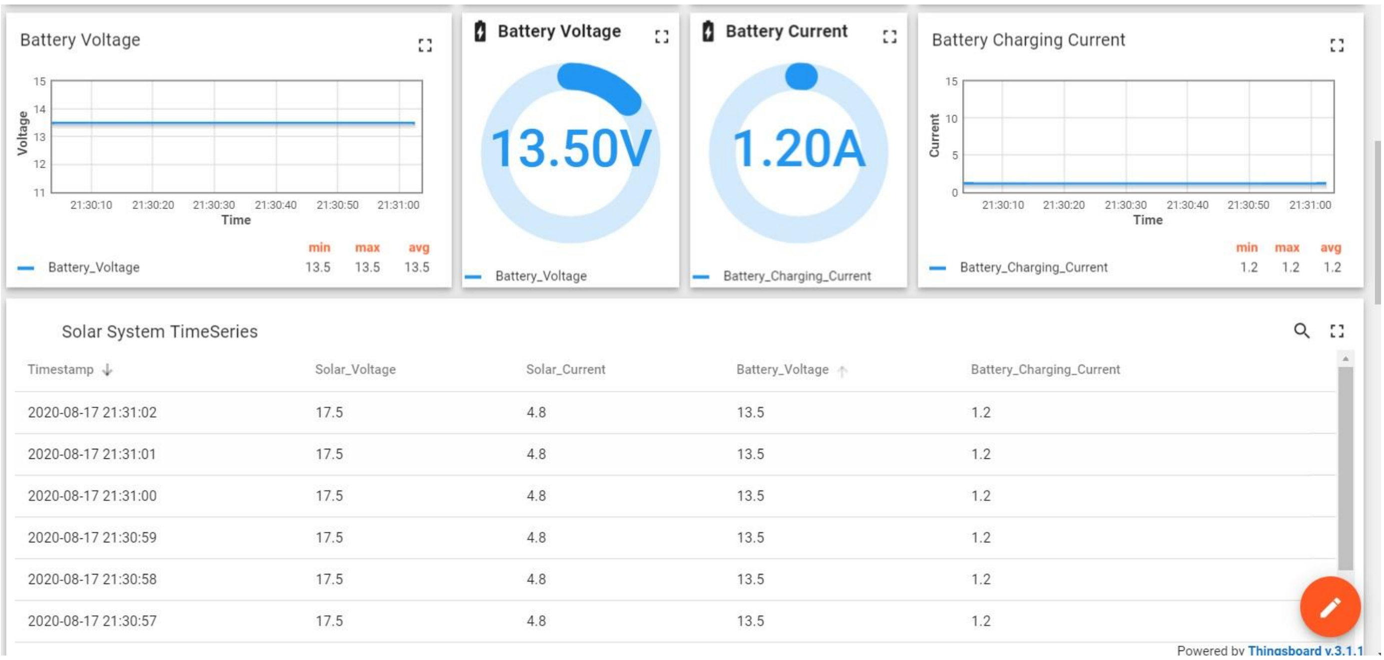
The following images below show the DASHBOARD WIDGETS tested with a telemetry sent from the TIVA BOARD.

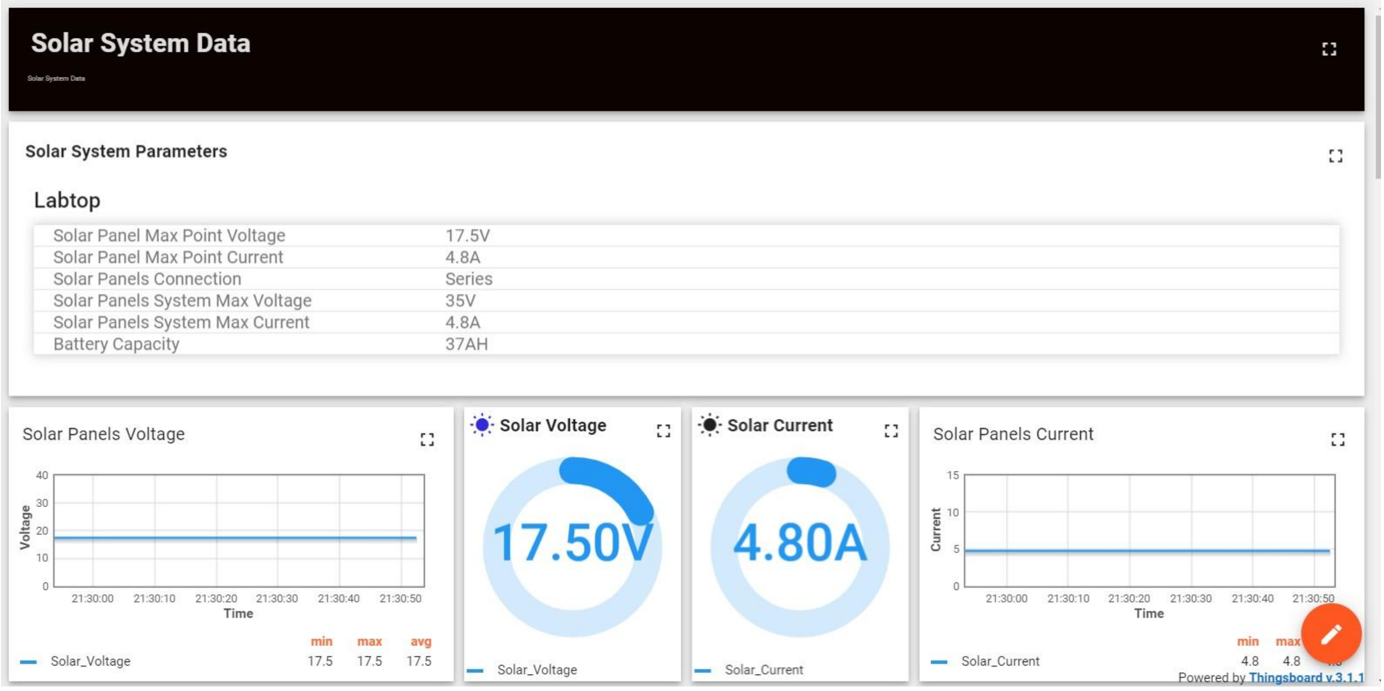



Unit Water Levels TimeSeries

Timestamp	Ammonia Filter Water Level	Tub Water Temperature	Storage Tank Water Level
2020-08-17 21:31:22	15	40	50
2020-08-17 21:31:21	15	40	50
2020-08-17 21:31:20	15	40	50
2020-08-17 21:31:19	15	40	50
2020-08-17 21:31:18	15	40	50

Items per page: 10 1 – 10 of 61





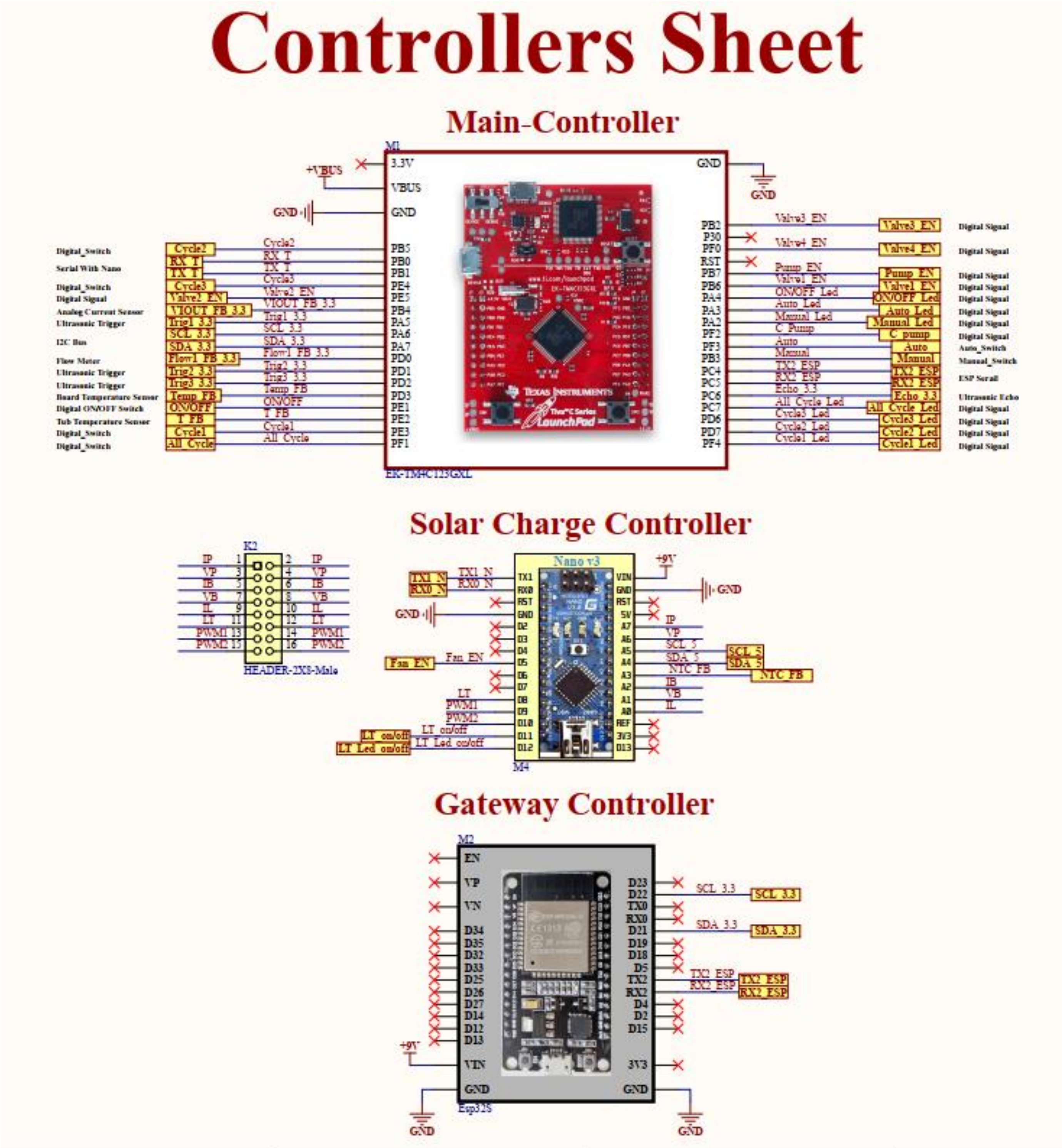
4.2.7 References.

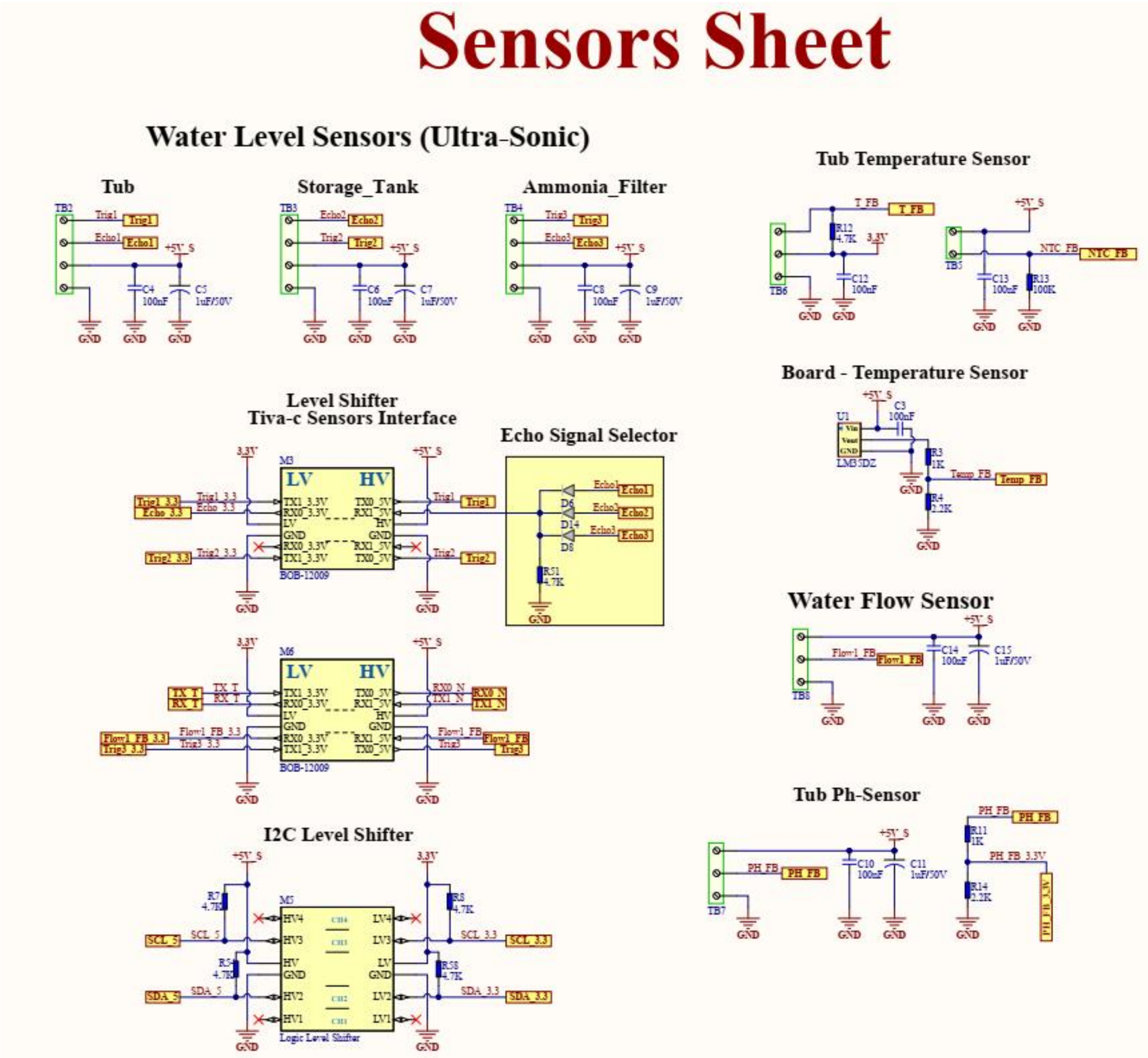
1.	**Esp32s-wroom-32-datasheet.**
2.	**PubsubClient library API Documentation (https://pubsubclient.knolleary.net/api.html).**
3.	**IoT system articles: (https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT), (https://www.zdnet.com/article/what-is-the-internet-of-things-everything-you-need-to-know-about-the-iot-right-now/), (https://www.newgenapps.com/blog/iot-ecosystem-components-the-complete-connectivity-layer/) and (https://www.kaaproject.org/what-is-iot-platform).**
4.	**ThingsBoard Documentation. (https://thingsboard.io/docs/).**

4.3 **ALTUIM design** of the **SYSTEM CONTROL BOARD**.

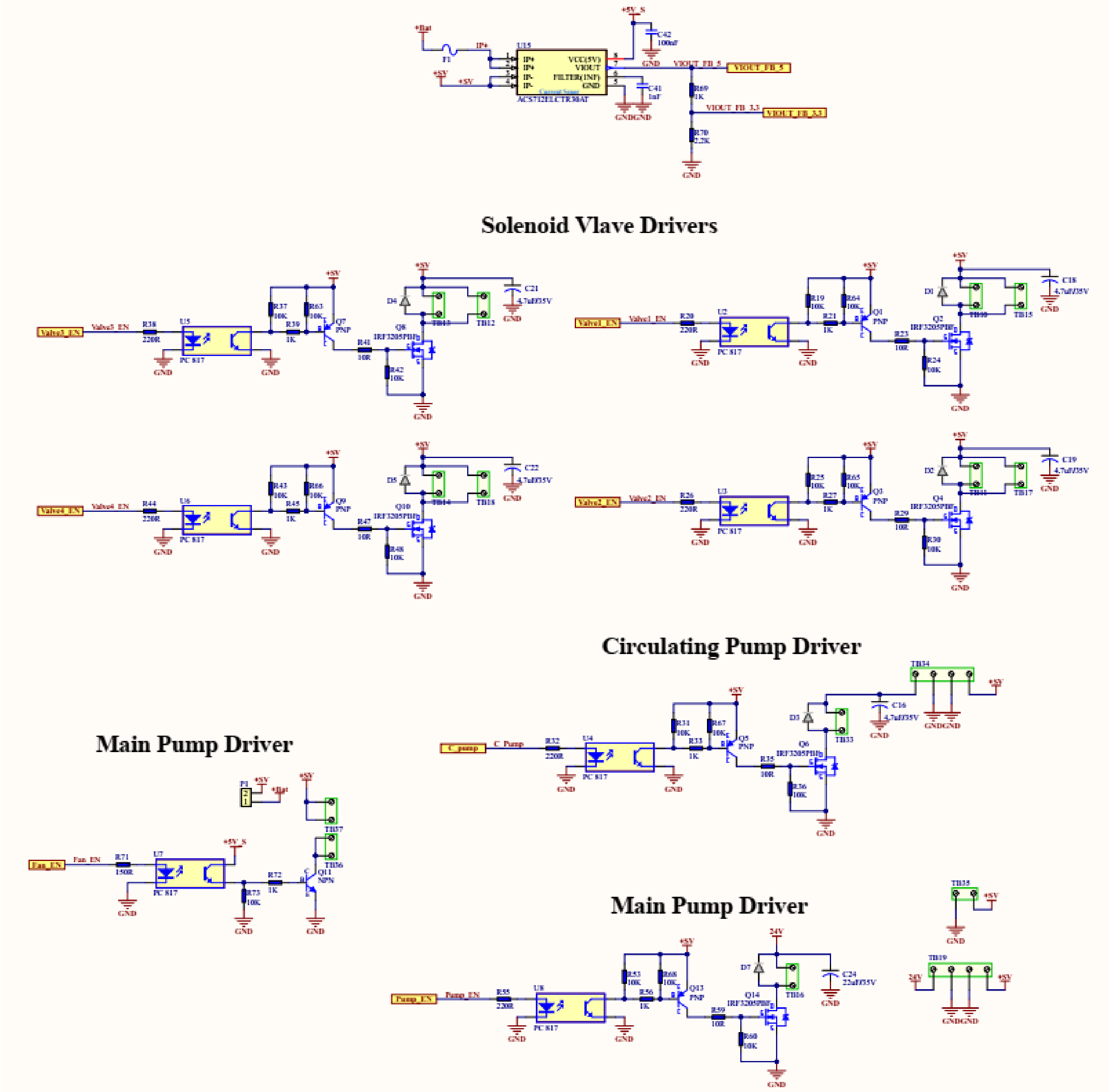
The ALTUIM DESIGNER software is a powerful PCB and electronic design software. This software was used to design the system control board connecting all the system controllers, sensors and actuators.

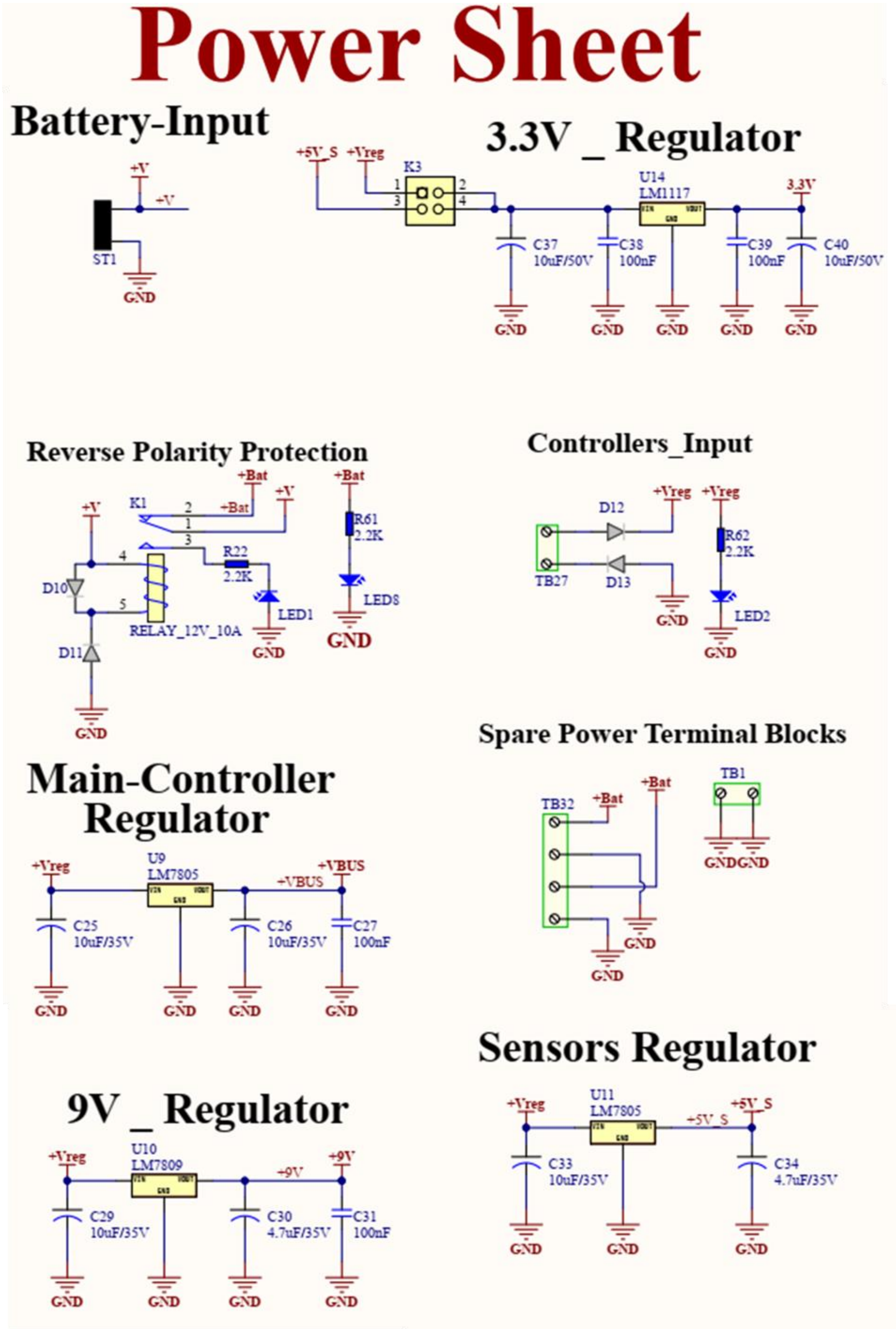
4.3.1 Design sheets.



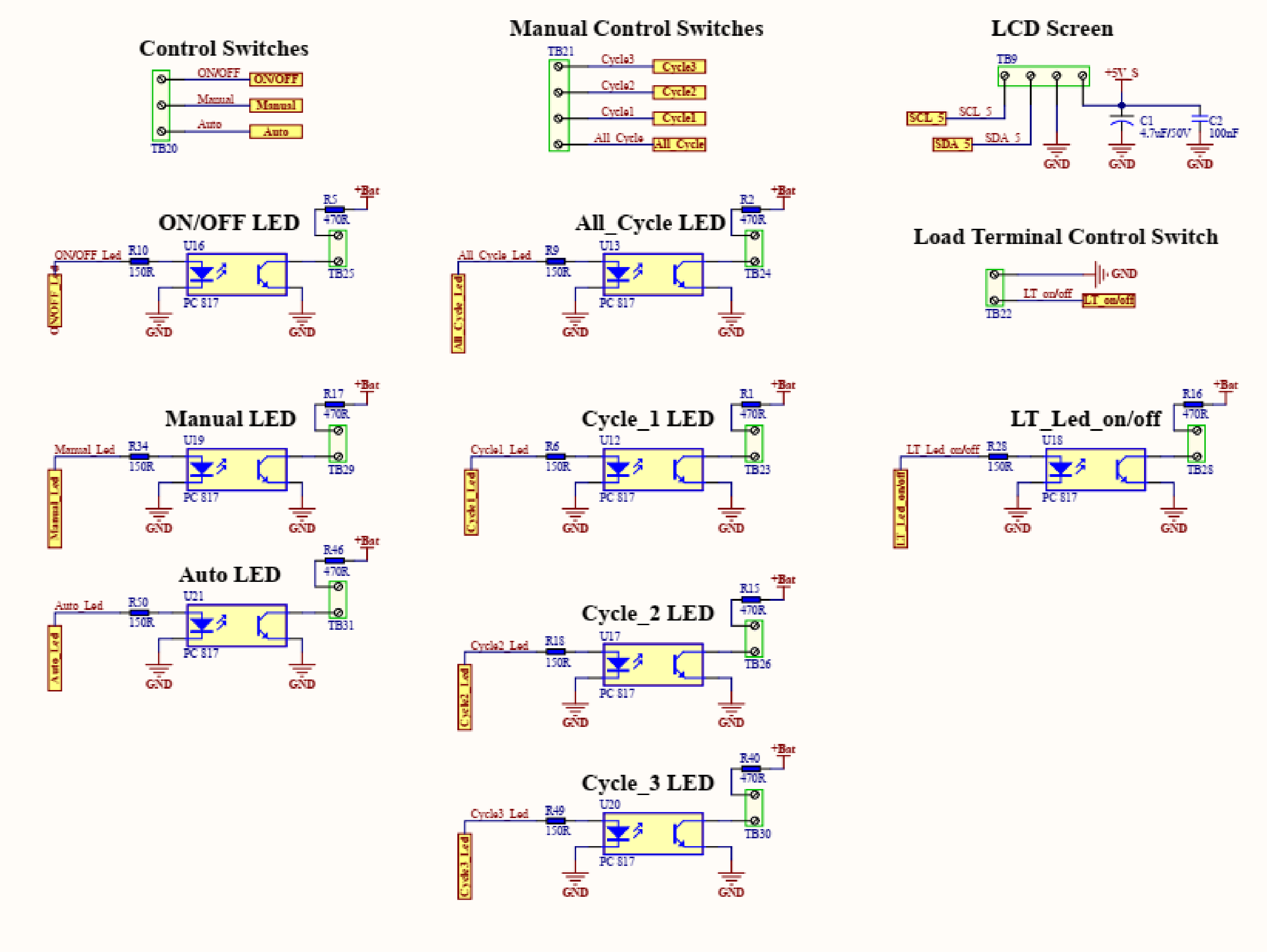

Sensors Sheet
Water Level Sensors (Ultra-Sonic)
Tub
Storage_Tank
Ammonia_Filter
Tub Temperature Sensor
Board - Temperature Sensor
Level Shifter
Tiva-c Sensors Interface
Echo Signal Selector
Water Flow Sensor
Tub Ph-Sensor
I2C Level Shifter
BOB-12009
Logic Level Shifter
LM35DZ
GND
+5V_S
3.3V

Actuators Driver Sheet




Power Sheet
Battery-Input
+V
+V
ST1
GND
3.3V _ Regulator
+5V_S
+Vreg
K3
1
2
3
4
U14
LM1117
3.3V
C37
10uF/50V
C38
100nF
C39
100nF
C40
10uF/50V
GND
Reverse Polarity Protection
+Bat
+V
K1
+Bat
+V
D10
D11
RELAY_12V_10A
R22
2.2K
LED1
GND
+Bat
R61
2.2K
LED8
GND
Controllers_Input
+Vreg
+Vreg
D12
D13
TB27
R62
2.2K
LED2
GND
Spare Power Terminal Blocks
TB32
+Bat
+Bat
TB1
GND
GND
Main-Controller Regulator
+Vreg
U9
LM7805
+VBUS
+VBUS
C25
10uF/35V
C26
10uF/35V
C27
100nF
GND
Sensors Regulator
+Vreg
U11
LM7805
+5V_S
+5V_S
C33
10uF/35V
C34
4.7uF/35V
GND
9V _ Regulator
+Vreg
U10
LM7809
+9V
+9V
C29
10uF/35V
C30
4.7uF/35V
C31
100nF
GND

Control Panel Sheet

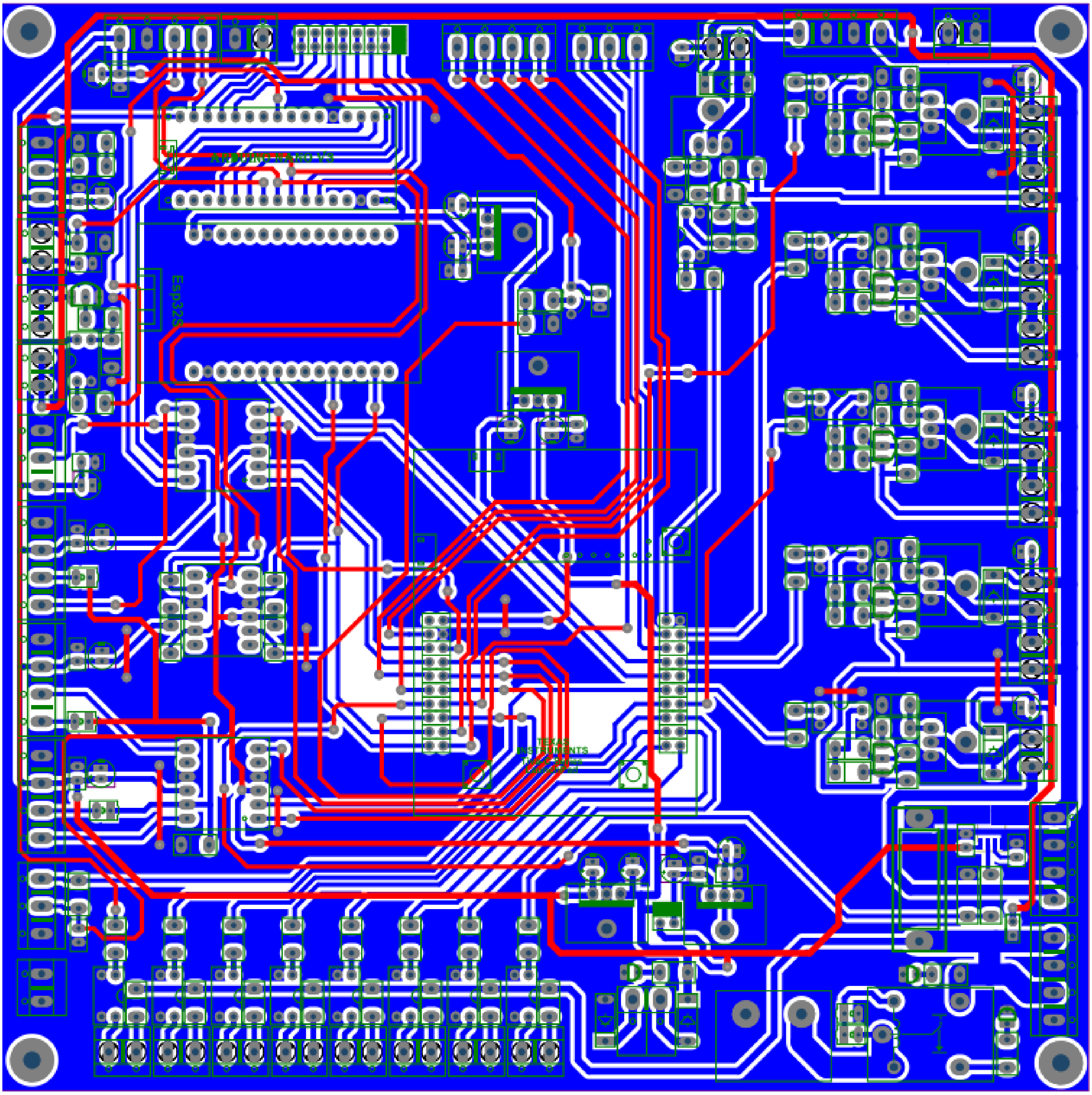


4.3.2 PCB layout.

The designed circuit, shown in the previous sheets, was implemented on a 20x20cm^2 board. The PCB board components was designed using a **double layer** approach with **a ground plane** at the bottom of the PCB board.

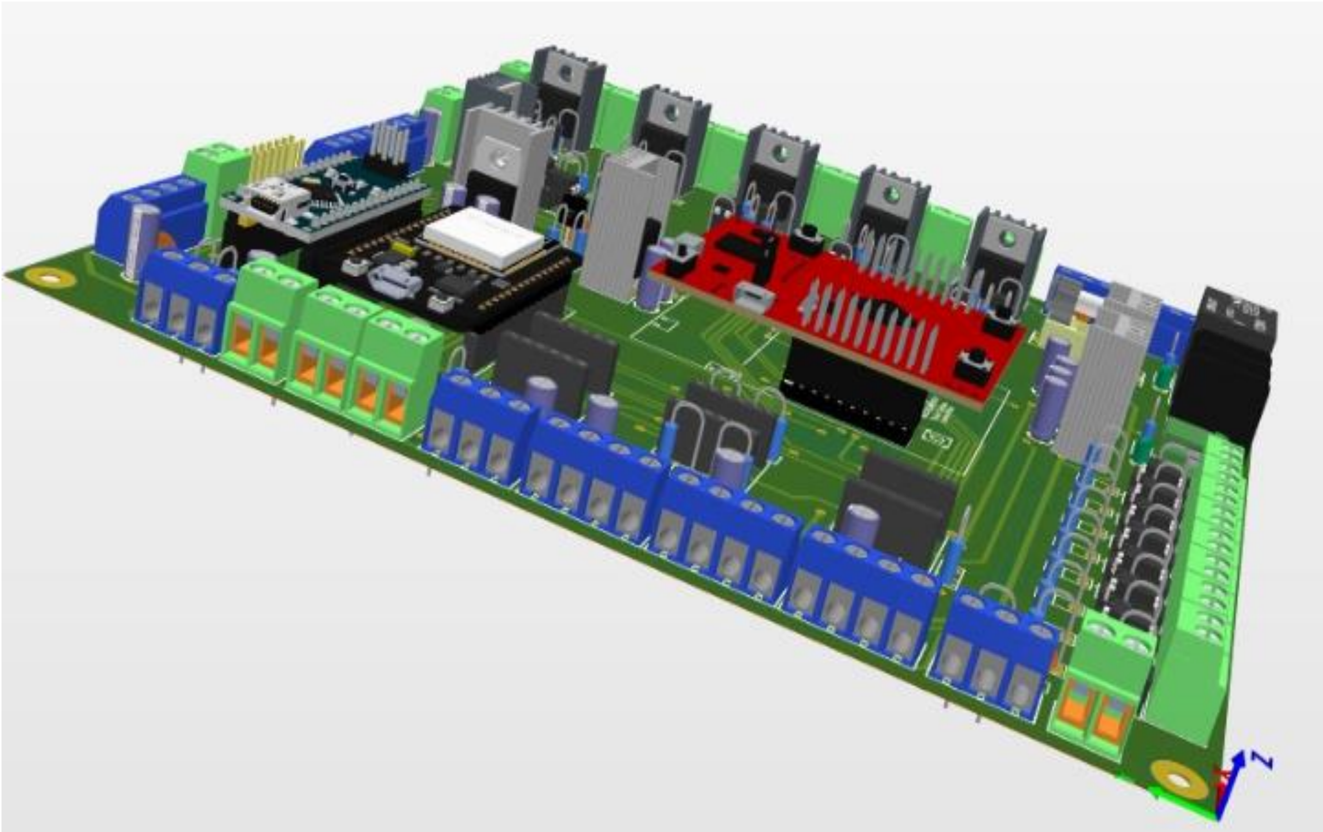
4.3.2.1 Routing diagram.

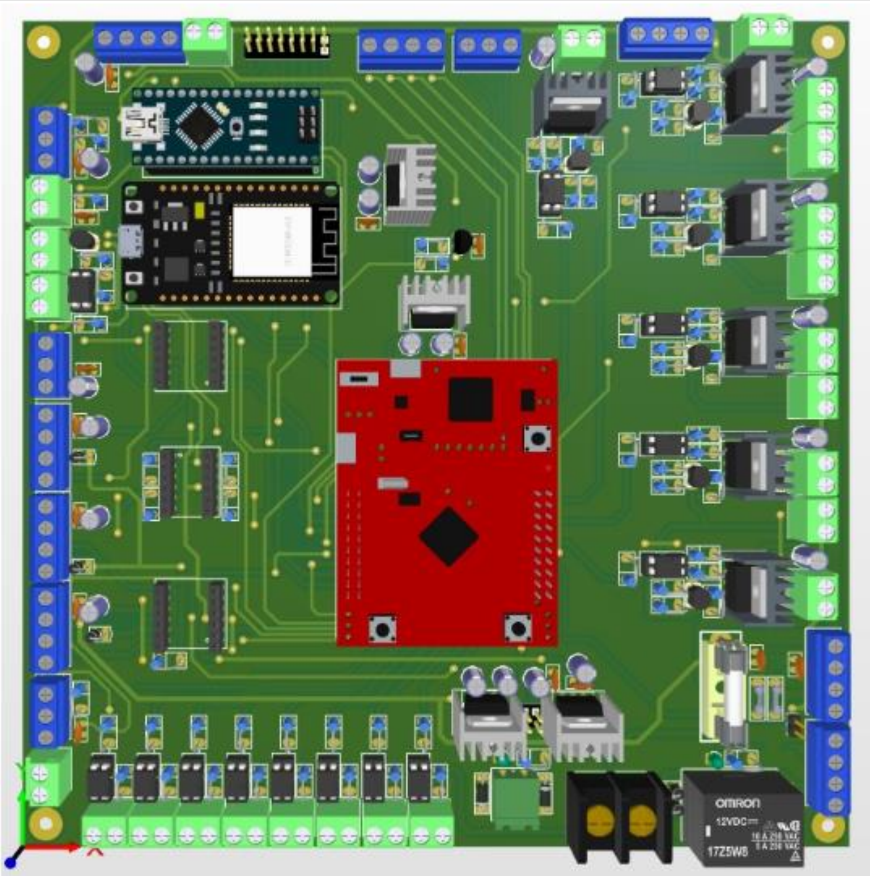
The figure below shows the routing diagram of the board. **The top layer tracks are shown in red. The bottom layer tracks and the ground plane are both shown in blue.**



4.3.2.2 **3D VIEW.**

The ALTUIM software also provides a 3D view of the board. The 3D view of the board is shown below.





4.3.3 Component sheet.

After finishing the design, a **component sheet** was exported from the ALTUIM software in PDF format.

Component list

Bill of Materials For Project [Tub_Board_V3.PrjPCB] (No PCB Document Selected)

Source Data From:	Tub_Board_V3.PrjPCB
Project:	Tub_Board_V3.PrjPCB
Variant:	None
Report Date:	8/16/2020 3:20:51 PM
Print Date:	16-Aug-20 3:21:04 PM

Altium
Think it, Design it, Build it™

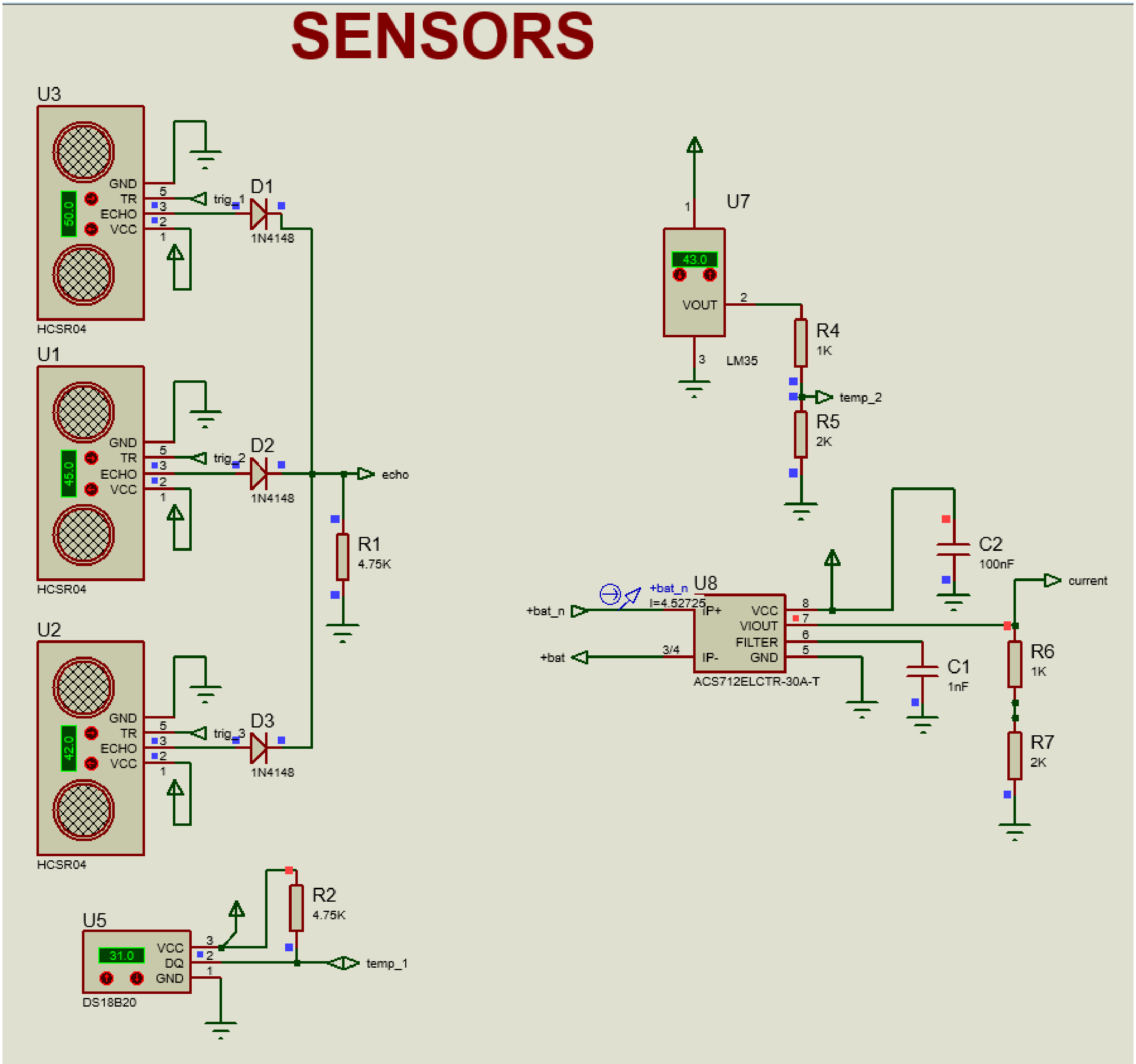
#	LibRef	#Column Name Error:Manufacturer	lumn Name Error:Manufacture	Column Name Error:PartTyp	Description	Footprint	#Column Name Error:Package Reference	Quantity
1	ECAP-4.7uF-50V				4.7uF ±20% 50V 5x11 1000Hrs @ 105℃ Radial,5x11mm Aluminum Electrolytic Capacitors - Leaded RoHS	ECAP 5X11X2MM		1
2	Ceramic_CAP_100nF					CCAP 0.1 N Y		14
3	ECAP-1uF-50V				1uF ±20% 50V 5x11 1000Hrs @ 105℃ Radial,5x11mm Aluminum Electrolytic Capacitors - Leaded RoHS	ECAP 5X11X2MM		5
4	ECAP-4.7uF-35V				4.7uF ±20% 35V 5x11 7000Hrs @ 105℃ Radial,5x11mm Aluminum Electrolytic Capacitors - Leaded RoHS	ECAP 5X11X2MM		7
5	ECAP-22uF-35V				22uF ±20% 35V 5x11 2000Hrs @ 105℃ 190mA @ 100kHz Radial,5x11mm Aluminum Electrolytic Capacitors - Leaded RoHS	ECAP 5X11X2MM		1
6	ECAP-10uF-35V				10uF ±20% 35V 5x11 2000Hrs @ 105℃ Radial,5x11mm Aluminum Electrolytic Capacitors - Leaded RoHS	ECAP 5X11X2MM		4
7	ECAP-10uF-50V				10uF ±20% 50V 5x11 1000Hrs @ 105℃ Radial,5x11mm Aluminum Electrolytic Capacitors - Leaded RoHS	ECAP 5X11X2MM		2
8	Ceramic_CAP_1nF					CCAP 0.1 N Y		1
9	DIODE					DIODE-1n400X_0.3		8
10	DIODE					DIODE-1N400X_0.1		5
11	FUSES&HOLDERS					FUSE HOLDER		1
12	Relay_12V_10A				SPDT Relay	RELAY_10A		1
13	HEADER-2X8-Male					HEADER-2X8		1
14	HEADER-2X2-Male					HEADER-2X2		1
15	LED					LED 3MM RED		1
16	LED					LED 3MM GREEN		2
17	Tiva-C				EK-TM4C123GXL: Tiva C Microcontroller LaunchPad Evaluation KitEK-TM4C123GXL: Tiva C Microcontroller LaunchPad Evaluation Kit	Tiva-C		1
18	Esp32S				ESP32 is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC ultra-low-power 40 nmtechnology	Esp32S		1
19	BOB-12009				Bi-Directional Logic Level Converter	BOB-12009		2
20	Arduino Nano					NANO V3		1
21	Logic Level Shifter				Logic Level Converter Bi-Directional - Works with 5V / 3.3V / 2.8V / 1.8V	Logic Level Shifter		1
22	Header - 2 - Male				Header, 2-Pin	PINHEADER X2		1
23	PNP					Transistor-TO-92A		6
24	IRF3205PBF				N Channel 55V 110A 4V @ 250uA 8mΩ @ 62A,10V 200W TO-220(TO-220-3) MOSFET RoHS	Transistor/Heatsink -TO-220		6
25	NPN					Transistor-TO-92A		1
26	R470R-THT				470R ±1% 1/4W ±100ppm/℃ Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		8
27	R1K-THT				1K ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		9
28	R2.2K-THT				2.2K ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		5
29	R150R-THT				150R ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		9
30	R4.7K-THT				4.7K ±1% 1/4W ±100ppm/℃ Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		6
31	R100K-THT				100K ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		1
32	R10K-THT				10K ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		19
33	R220R-THT				220R ±1% 1/4W ±100ppm/℃ Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		6
34	R10R-THT				10R ±1% 1/4W ±100ppm/℃ Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_5.08mm-1/4W		6
35	R1K-THT				1K ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_7.62mm-1/4W		1
36	R2.2K-THT				2.2K ±1% 1/4W ±100ppm/°C Axial Metal Film Resistor_ Throuh Hole Technology RoHS	R-THT_7.62mm-1/4W		1
37	SCREW TERMINAL				Barrier Terminal Block 2 Pin with cover 300V/25A	SCREW TERMINAL		1
38	Terminal block 2 pin				Terminal Block 2 Pin 10A 300V	AK500/2		24
39	Terminal block 4 pin				Terminal Block 3 Pin 10A 300V	AK500/4_BLUE		8
40	Terminal block 3 pin				Terminal Block 3 Pin 10A 300V	AK500/3_blue		4
41	Terminal block 2 pin				Terminal Block 2 Pin 10A 300V	AK500/2 - pluggable		1
42	LM35DZ				Precision Centigrade Temperature Sensors	LM35DZ		1
43	PC 817				4-Pin Phototransistor Optocoupler	IC_DIP4		15
44	LM7805				78xx Regulators	V-REG/Heatsink - TO - 220		2
45	LM7809				78xx Regulators	V-REG/Heatsink - TO - 220		1
46	LM117				IC LM1117-3.3V	V-REG/Heatsink - TO - 220		1
47	ACS712ELCTR30AT				Sensor: current; Package: SO8; Usup: 4.5Â·5.5VDC; Iin: Â± 30A; 66mV	ACS712_SOIC127P600X175-8N		1
Approved			Notes					205

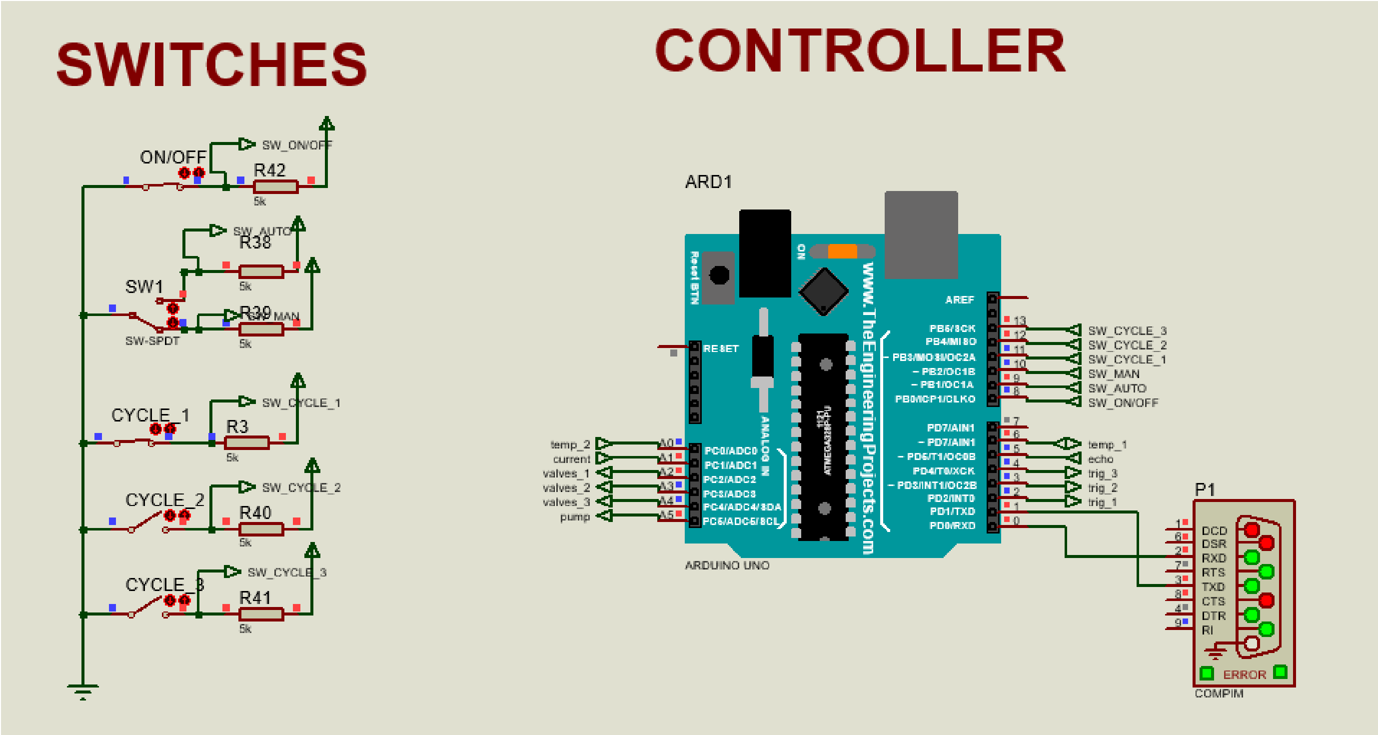
4.4 **PROTEUS SIMULATION** of the **SYSTEM CONTROL BOARD**.

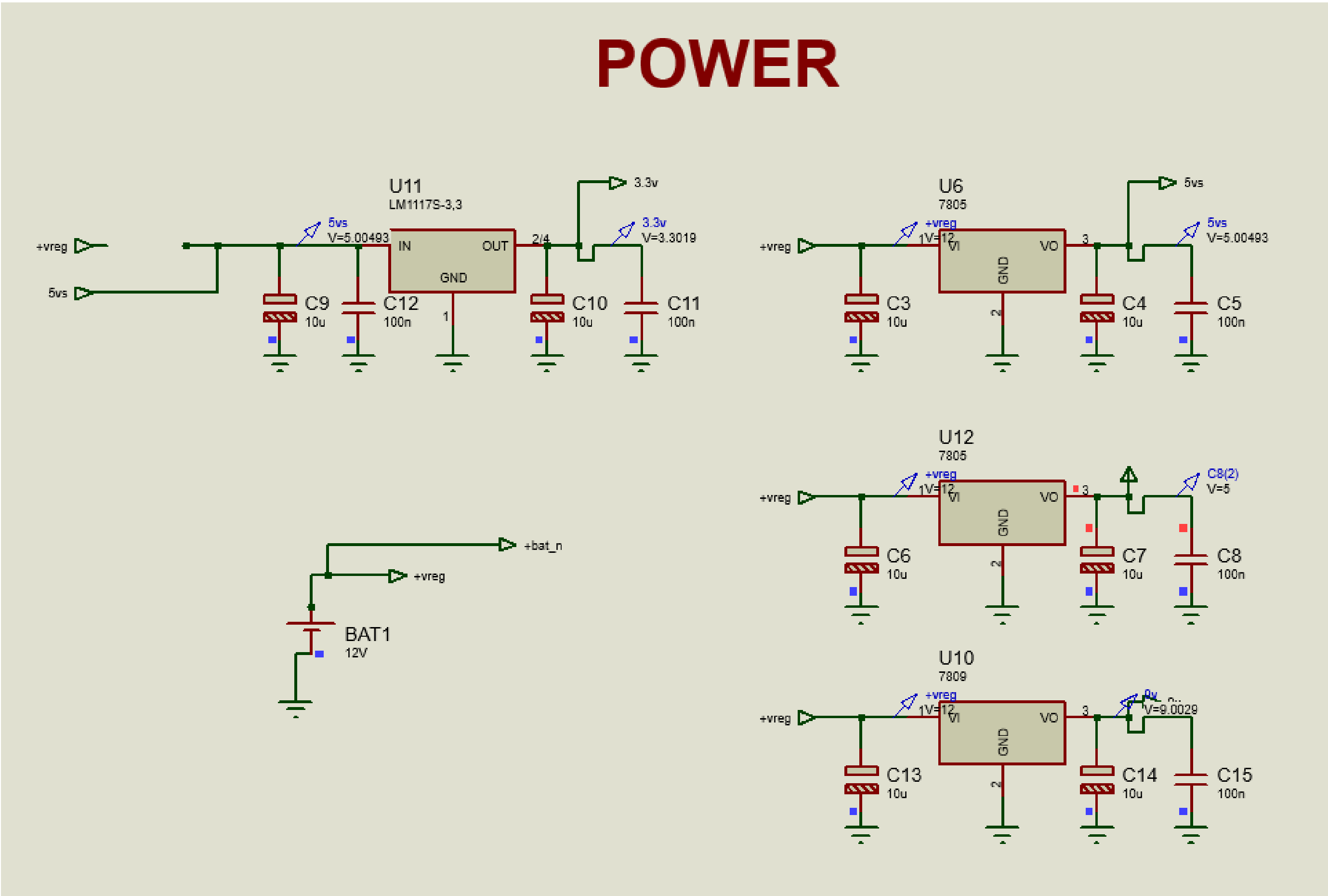
The circuit simulation was done on proteus and the sensors values were exported to a virtual com port (COM101). COM101 was created specifically to connect the simulation with the IOT section.

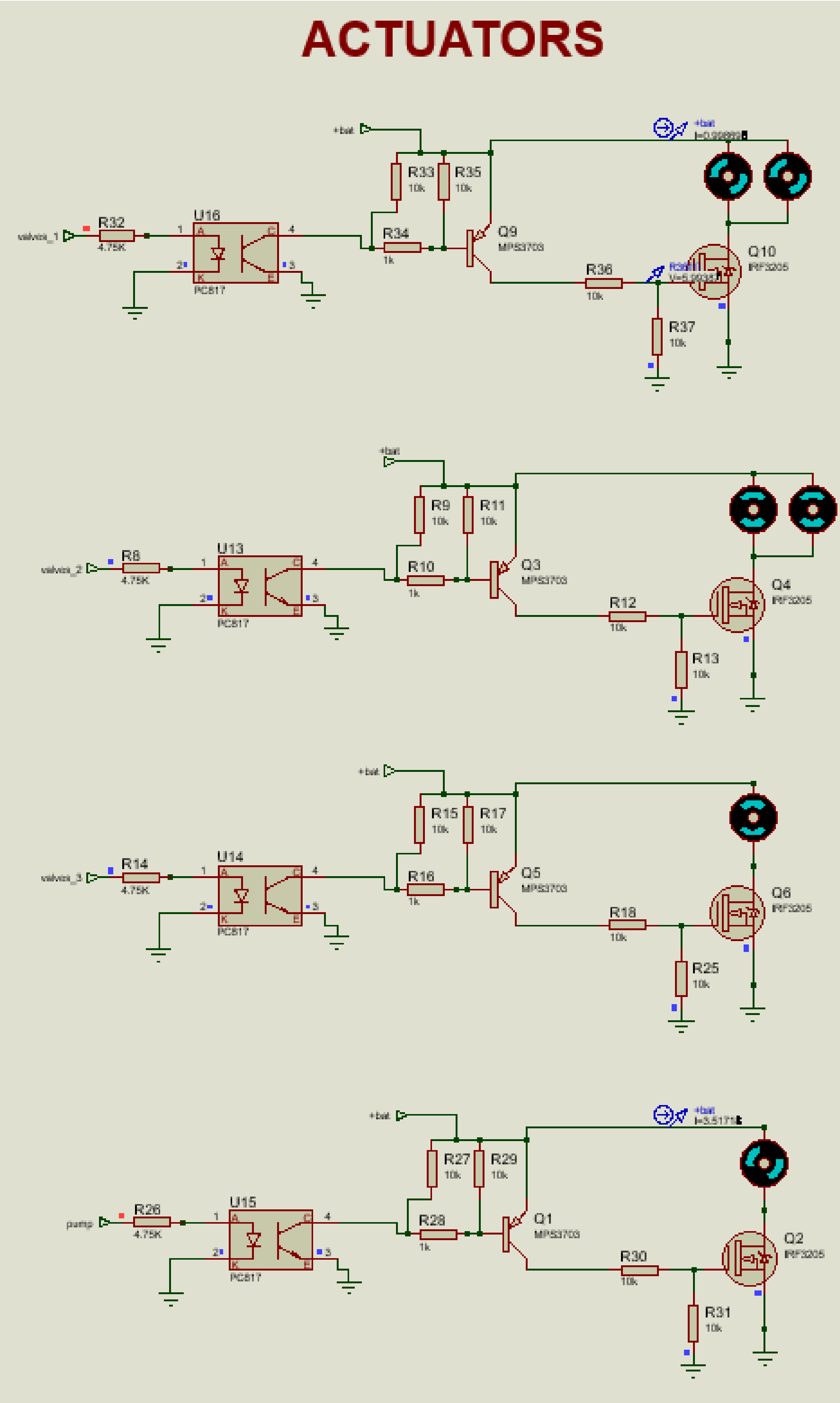
The TIVA board has no proteus model so an Arduino board was used instead to run a similar code. This simulation was run with cycle 1 turned on. Then, the telemetry message was received on COM101. The following set of images show the simulation running with man mode and cycle 1 running.

Note: the Arduino code and the HEX file flashed on the controller simulation block are attached with the project files.




SWITCHES
CONTROLLER
ON/OFF
SW_ON/OFF
R42
5k
SW_AUTO
R38
SW1
SW_MAN
R39
SW-SPDT
CYCLE_1
SW_CYCLE_1
R3
CYCLE_2
SW_CYCLE_2
R40
CYCLE_3
SW_CYCLE_3
R41
ARD1
ARDUINO UNO
www.TheEngineeringProjects.com
AREF
RESET
temp_2
current
valves_1
valves_2
valves_3
pump
SW_CYCLE_3
SW_CYCLE_2
SW_CYCLE_1
SW_MAN
SW_AUTO
SW_ON/OFF
temp_1
echo
trig_3
trig_2
trig_1
P1
DCD
DSR
RXD
RTS
TXD
CTS
DTR
RI
ERROR
COMPIM


POWER
U11
LM1117S-3,3
+vreg
5vs
V=5.00493
IN
OUT
GND
3.3v
V=3.3019
C9
10u
C12
100n
C10
10u
C11
100n
U6
7805
V=12
VI
VO
GND
V=5.00493
C3
10u
C4
10u
C5
100n
U12
7805
C8(2)
V=5
C6
10u
C7
10u
C8
100n
+bat_n
BAT1
12V
U10
7809
V=9.0029
C13
10u
C14
10u
C15
100n


ACTUATORS
+bat
R32
4.75K
U16
PC817
R33
10k
R35
10k
R34
1k
Q9
MPS3703
R36
10k
R37
10k
Q10
IRF3205
R8
4.75K
U13
PC817
R9
10k
R11
10k
R10
1k
Q3
MPS3703
R12
10k
R13
10k
Q4
IRF3205
R14
4.75K
U14
PC817
R15
10k
R17
10k
R16
1k
Q5
MPS3703
R18
10k
R25
10k
Q6
IRF3205
pump
R26
4.75K
U15
PC817
R27
10k
R29
10k
R28
1k
Q1
MPS3703
R30
10k
R31
10k
Q2
IRF3205

COM101 - PuTTY

```
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I,4,T1,31,T2,43,L1,48,L2,43,L3,40
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I,4,T1,31,T2,43,L1,48,L2,43,L3,40
I,4,T1,31,T2,43,L1,48,L2,43,L3,40
```

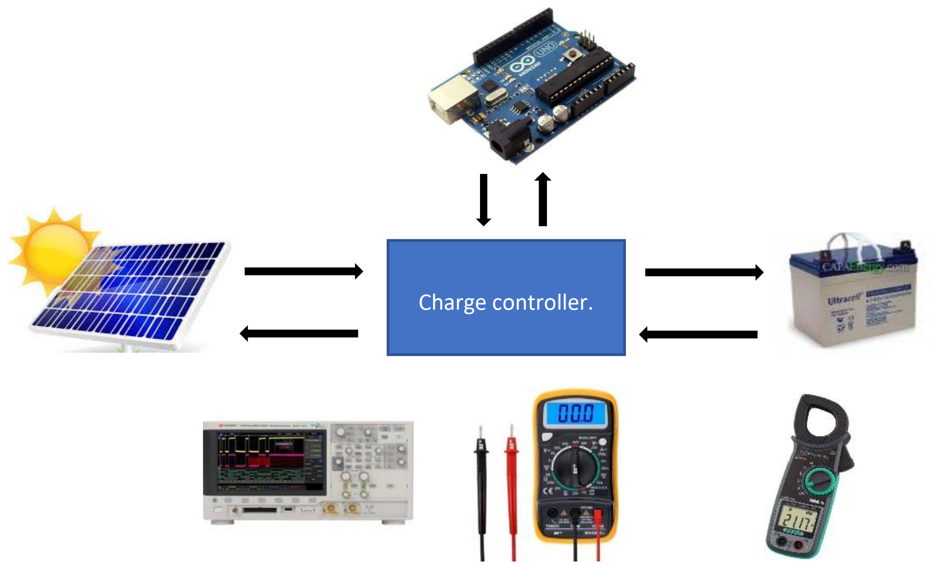
Chapter 5

Experimental setup and results.

5.1 Testing of the MPPT solar subsystem.

5.1.1 Testing setup.

1- The panels are placed under the sunlight ant a suitable angle.
2- The two terminals of the solar array are connected to the input side of the charge controller circuit.
3- The battery is connected to the other side of the charge controller.
4- The clamp meter is used to measure the charging current of the battery.
5- A voltmeter is used to measure the charging voltage.
6- A scope is used to monitor the signals at different parts of the setup.



5.2.2 Procedure.

1- The scope is used to monitor the PWM signal at the controller end.
2- The scope is used to ensure that the TLP gate drive circuit is controlling the gate of the MOSFET correctly.
3- The voltmeter is used to measure the charging voltage of the battery to ensure it is on the level selected in the PWM algorithm code on the Arduino board.
4- The ammeter is used to measure the charging current of the battery.

5.2.3 Results.

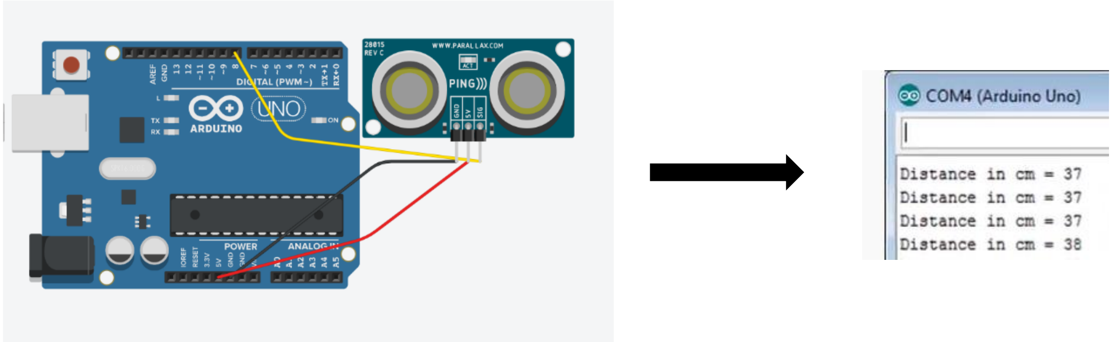
1- The measured voltage is always at the level set on the PWM algorithm.
2- The measured charging current decreases as the battery charges.

5.2 Testing of the water circulation network.

5.1.1 Taking level measurements for the manual mode.

Procedure:

1- After implementing the water circulation section an **ultrasonic paired with an Arduino board** was used to take the necessary measurements needed for the control circuit.



2- This setup was used to measure the **maximum and minimum allowable levels in each tank.**

3- **The results appear on the serial monitor.** These results were recorded in table format.

Results:

The following table lists the **maximum and minimum level values allowed in the manual mode.**

TANK 1 (TUB).	MAX. LEVEL	30 Cm
	MIN. LEVEL	0 Cm
TANK 2 (STORAGE TANK).	MAX. LEVEL	50 Cm
	MIN. LEVEL	10 Cm
TANK 3 (AMMONIA TANK).	MAX. LEVEL	12 Cm
	MIN. LEVEL	3 Cm

5.2.2 Taking power consumption measurements for each cycle.

Procedure:

1- After implementing the water circulation section, the manual mode was used to measure the power consumption in each cycle.

2- The current measurements were taken using a CLAMB METER.

Results:

The following table lists the **CURRENT MEASUREMENTS.**

CYCLE 1	I_{VALVE} = 0.6 A	I_{TOT} = 0.6 A
CYCLE 2	I_{VALVES} = 0.5 +0.5 = 1 A	I_{TOT} = 4.5 A
	I_{PUMP} = 3.5 A	
CYCLE 3	I_{VALVES} = 0.6 +0.5 = 1.1 A	I_{TOT} = 4.7 A
	I_{PUMP} = 3.6 A	

5.3 Testing of the control and IOT subsystem.

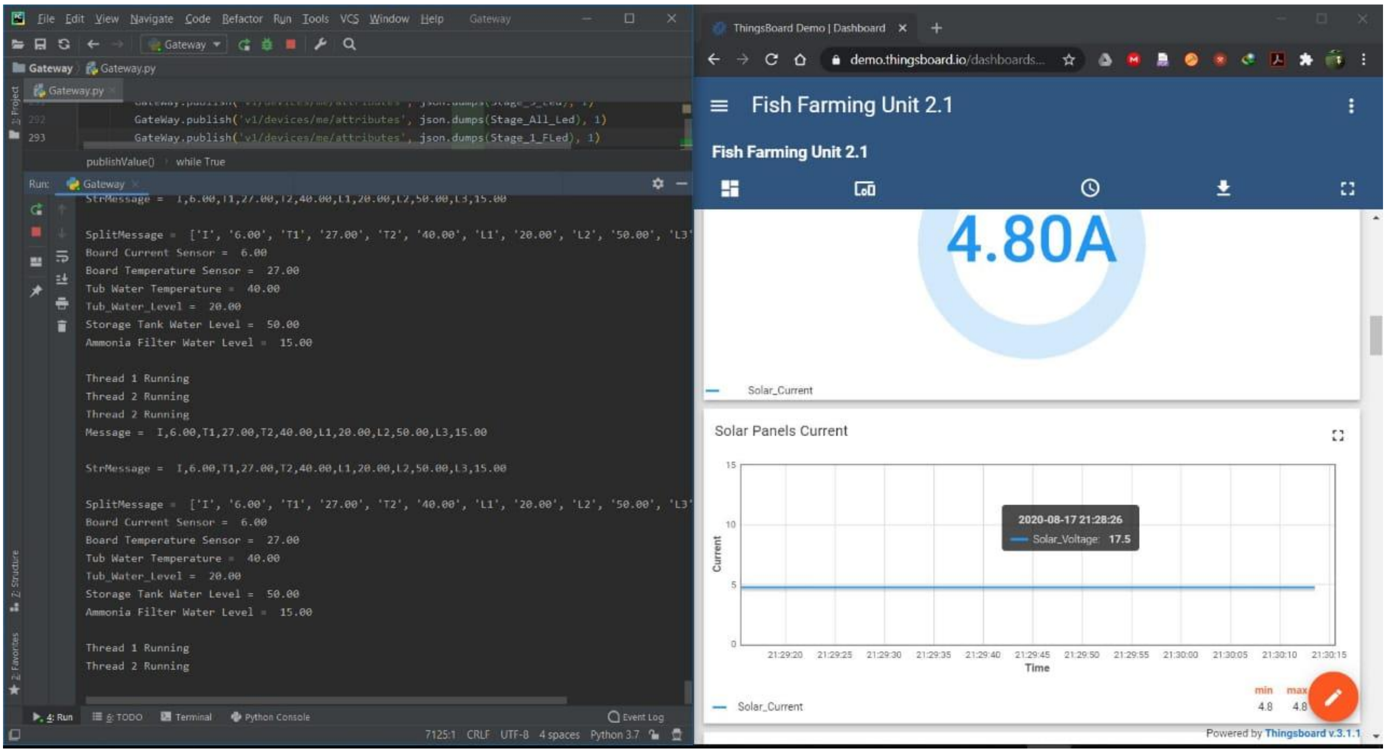
5.3.1 Testing the communication link.

Procedure:

1- A telemetry message was sent from the main controller on UART4 to the gateway (PC).
2- The pc maps the USB serial connection to a virtual com port.
3- the IOT compiler software receives the telemetry message from that com port after recognizing it and displays the telemetry message on the terminal.
4- The IOT compiler processes the message and publishes the measurements topic to the cloud (broker).
5- The dashboard receives the measurements topic and displays the measurements on the dashboard widgets.

Results:

1- The sent telemetry from the TIVA BOARD received successfully by both the gateway (PC) and the cloud.
2- Data is displayed properly on the widgets of the cloud DASHBOARD.



5.3.2 Testing the control section with the mechanical subsystem.

1- After the control circuit was connected to the system, **we tested both the manual and automatic modes.**
2- We checked that each button on the panel was doing its function properly.

Chapter 6

Conclusions and future work.

6.1 Conclusions.

- A **standalone battery-based system** introduces too many difficulties. Therefore, if the unit is in a place where grid is available a **grid-based system** would be a better choice.
- Although DC pumps have an advantage over AC pumps in terms of higher efficiency and no requirement of an inverter for operation, the cost of DC pumps is higher. Also, the repair and maintenance of DC pumps are difficult in rural and remote areas due to lack of service centers in these areas. Therefore, **the choice in most cases is an AC pump.**
- When fluid flows will be a pressure drop that occurs as a result of resistance to flow (energy loss). **Friction loss** takes place as the fluid passes through any pipes, trunks, bends and valves. Therefore, **bends should be reduced as much as possible**.
- The water quality should be monitored either by introducing more water quality sensors or a water quality analyzer. Similar units make use of a water quality analyzer to completely monitor the water quality.
- The chosen cloud platform **"THINGSBOARD.IO, free version"** is not reliable as the servers go down very frequently. Therefore, a premium cloud platform would give the IOT section more reliability.
- It is always better to test system components separately before assembling them. This helps in fast and efficient trouble shooting of problems.

6.2 Future additions and adjustments.

6.2.1 Future additions to the MPPT solar Subsystem.

- Implementing the MPPT converter that was designed and simulated in chapter 4.
- Adding short circuit protection to the system.
- Providing proper earthing for the system to protect the electronic components from lightning.

6.2.2 Future additions to the mechanical system.

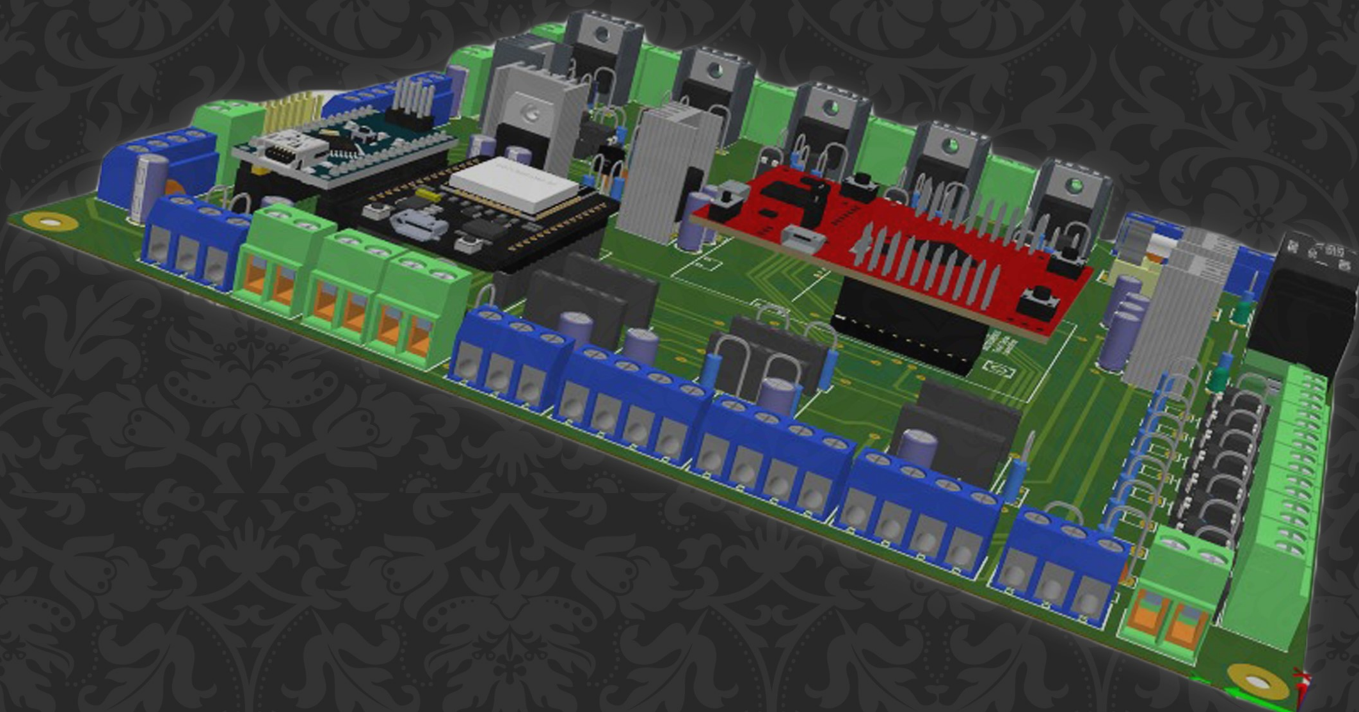
- **A solar traction servo** mechanism to improve the panels performance throughout the day.
- **Pressure gauges to provide** necessary measurements to **detect leakage and blocked pipes.**
- **Doing the pump selection calculations to** choose a pump capable of suppling the **required static head** working **near the maximum pump efficiency**. This would help in **lowering the power consumption of the pump.**

6.2.3 Future additions to CONTROL AND IOT SUBSYSTEM.

- Introducing a **power saving mode** in the controller section to be used in case the system is low in power.
- Introducing a **mobile application** to monitor and control the unit instead of just using the cloud DASHBOARD.

6.3 A practical approach.

In Egypt, drinking water filters are used almost everywhere. These filters have a 1:1 **waste to pure water ratio** at best. The waste water increases the number of filter stages increases. This waste water is suitable for farming the most popular type of fish in Egypt which is **Tilapia**. This is why this project finds it place in the market a a perfect way to make use of buildings' roofs. **A central water filter would supply the building with clean drinking water and the unit with the waste water needed to farm Tilapia.** In that case, since the grid is available to the unit it is better to use a GRID-based system instead of a BATTERY-based system. **If a company adopts such approach, it can even rent out buildings' roofs making a decentralized fish farm. A group of such decentralized units form a production area. Fish production in each area can be supplied locally to the markets inside it.**



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