Water and Energy Conservation Grow System: Aquaponics and Aeroponics with a Cycle Timer

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2 Abstract

What some experts call the "blue gold"; water is a major issue in this world. There is only so much water and the reliability and cleanliness of water is what many developing countries are dealing with today. Countries around the world are facing problems with reliable water to grow enough food for their villages and homes. Is there is a way to minimize water consumption while optimizing growth in plants for food? One solution can be seen through both Aeroponics and Aquaponics. This project explores the potential of providing larger quantities of food to areas where water may be in short supply. There are four main components: the cycle timer, solar panels, the Aeroponics / Aquaponics system, and live fish.

Aeroponics is a system thru which the roots are suspended in the air and saturated with water at designated time intervals. The benefit to this style of growing is the major reduction in water consumption compared to the traditional soil farming. With Aeroponics a farmer can grow certain types of food faster and bigger while using less water.

Aquaponics, the second system, utilizes a combination of fish and plants to create a balanced system. In this arrangement fish waste (ammonia) is converted into nitrate by two types of bacteria in a series of chemical reactions. The plants then use the nitrate rich water for growth while simultaneously "cleaning" the water for the fish and removing potentially harmful nitrogen buildup. Without each other's contribution to the system, the system would fail. The grow bed is designed to be a filter for the fish and also a growing area for the plants. This type of filter is called a bio-filter, which has living bacteria that breakdown the ammonia. This process is called the nitrogen cycle.

According to Aquaponics Earth, Aquaponic systems can conserve up to 99.75% of the water used by continuously re-circulating the system. Also that Aquaponics uses 90% less water than conventional farming techniques (Aquaponics Earth, 2012)

The cycle timer is made with 4 integrated circuits; a 555 timer, two counter chips, and a flip-flop. The cycle timer was the most logical choice for this project as it allows the user to choose the specific ON / OFF times as required by the plants in the system.

One of the goals in this project was to be able to run this system virtually anywhere. This concept included the use of solar panels. The solar panels are used to charge the battery through a charge controller with the suns energy. The DC energy is then converted into AC through an inverter. The size or number of the solar panels will depend on the size of the grow system. Also, solar can be used as a backup system if the main power goes out.

3 Introduction

This project started as a means to grow plants in areas not normally able to do so. Decrease water consumption while optimizing the growth and the size of plants. When compared to traditional agriculture Aeroponics uses limited water consumption. This system has had success in desert areas such as Saudi-Arabia and Israel. (Ziegler, 2005, p. 6) I wanted to push the envelope and to create a connection between my interest in plants and electronics. As an Electrical Engineer student from Cal Poly I researched the possibility of providing food for countries of water scarcity by means of future farming techniques and technology.

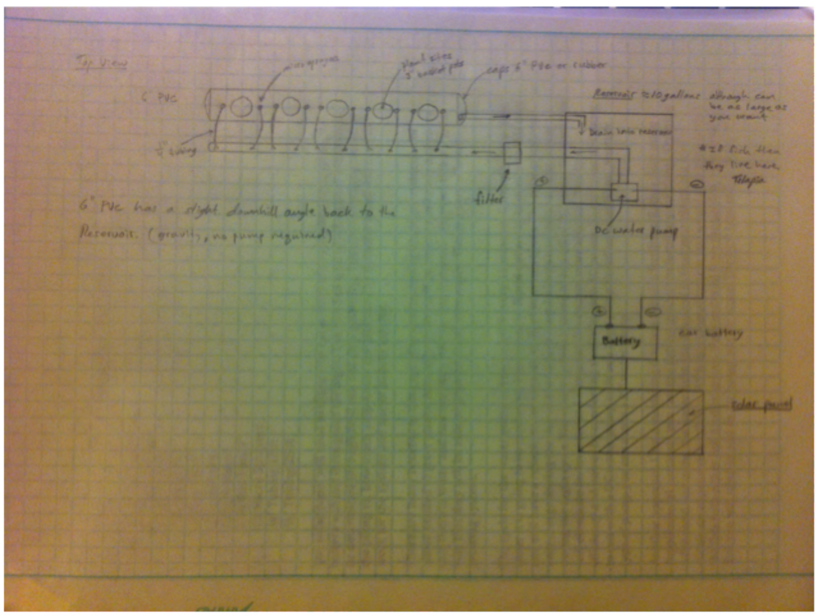

Figure 3-1: Initial Aeroponics Setup

4 System Specifications/Background

4.1. Cycle Timer Components

The cycle timer is made of 4 integrated chips (IC): 555 timer, 2 counters, and a flip-flop. The design included 4 resistors, 3 capacitors, 4 diodes, solid-state relay, and a 9V Battery

1x MC14013BCP (D Flip-Flop)
1x NE555P (555 Timer)
2x CD4020BE (Counter Chip)

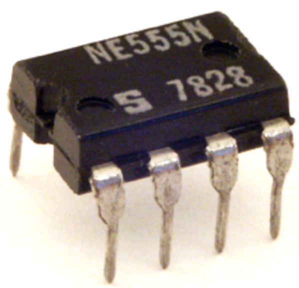

Figure 4-1: NE555P (555 Timer)

Figure 4-2: CD4020BE (Counter Chip)

Figure 4-3: MC14013BCP (D Flip-Flop)

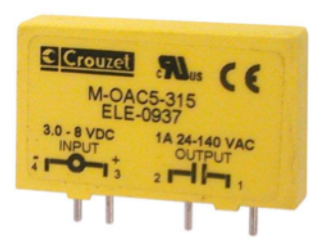

Figure 4-4: Solid State Relay DC to AC

Resistors: 1k, 10k, 10k, and 130k (Ohms)

Capacitors: 10p, 0.01p, and 68p (Farads)

Solid State Relay: DC to AC

Diodes: (4x)

LED: (2x)

Rotary Switches: (2x)

4.1.1. Timer intervals

The ON / OFF time intervals are set by the cycle timer. Depending on the size and maturity of the plant the timer intervals are changed accordingly.

For younger or new plants: 1 min ON, 5 min OFF
For mature or older plants: 1 min ON, 15 min OFF

The above timer intervals are just guidelines and need to be adjusted accordingly. For instance if you are in a very dry or sunny area the OFF time needs to be reduced. In a place of wet or humid area the OFF time may need to be increased. As a rule of thumb, the OFF time should be set a few minutes before the plants start to “droop” or show signs of drying out. The ON time isn’t as critical because the excess water is returned back to the reservoir. In other words the critical part is not drowning the roots, but rather the roots drying out.

ON TIME (Rotary Switch Locations)

1. 30sec	PIN 5
2. 1min	PIN 4
3. 4min	PIN 13
4. 8min	PIN 12
5. 34min	PIN 15
6. 68min	PIN 1

TABLE 4-1: ON TIMER PINS

OFF TIME (Rotary Switch Locations)

1. 1min	PIN 4
2. 4min	PIN 13
3. 8min	PIN 12
4. 34min	PIN 15
5. 68min	PIN 1
6. 2hr15min	PIN 2

TABLE 4-2: OFF TIMER PINS

All Possible Locations

1. 2sec	PIN 9
2. 16sec	PIN 16
3. 32sec	PIN 5
4. 1min	PIN 4
5. 2min	PIN 6
6. 4min	PIN 13
7. 8min	PIN 12
8. 17min	PIN 14
9. 34min	PIN 15
10. 68min	PIN 1
11. 2hr15min	PIN 2
12. 4hr30min	PIN 3

TABLE 4-1: ALL PINS

4.1.2. Cycle Timer Schematic

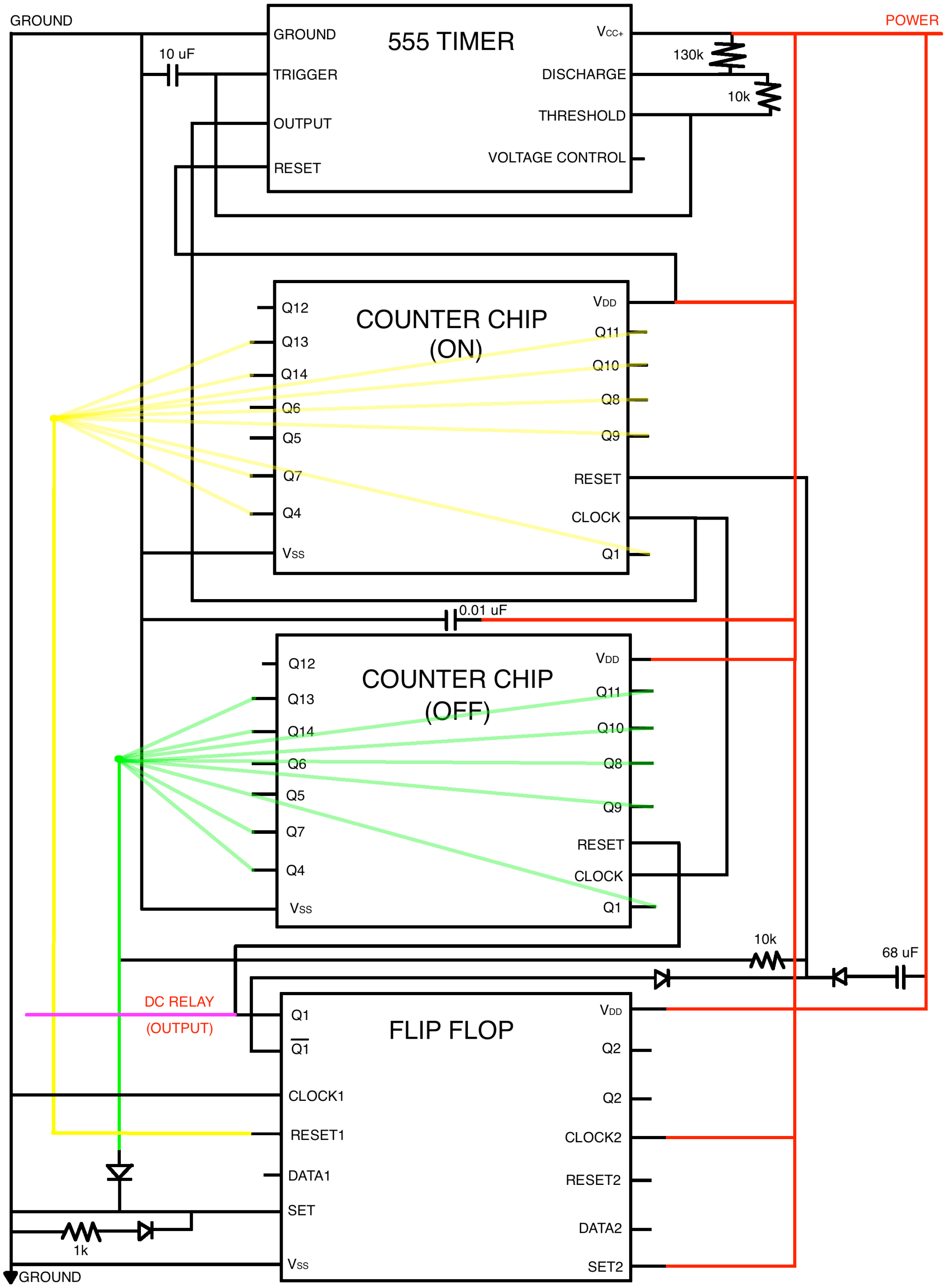

Figure 4-5: Cycle Timer Wiring Diagram

4.1.3. Outlet Wiring

Pin 1 on the flip-flop is the Q1 output signal. This is connected to the input (DC) of the solid-state relays positive terminal and the negative terminal is connected to the ground. The output of the solid-state relay is the AC side, which is connected to the black or hot wire on the AC outlet. This will allow current to flow when the relay switch is closed thus turning on the outlet. Below is a diagram of how it is connected.

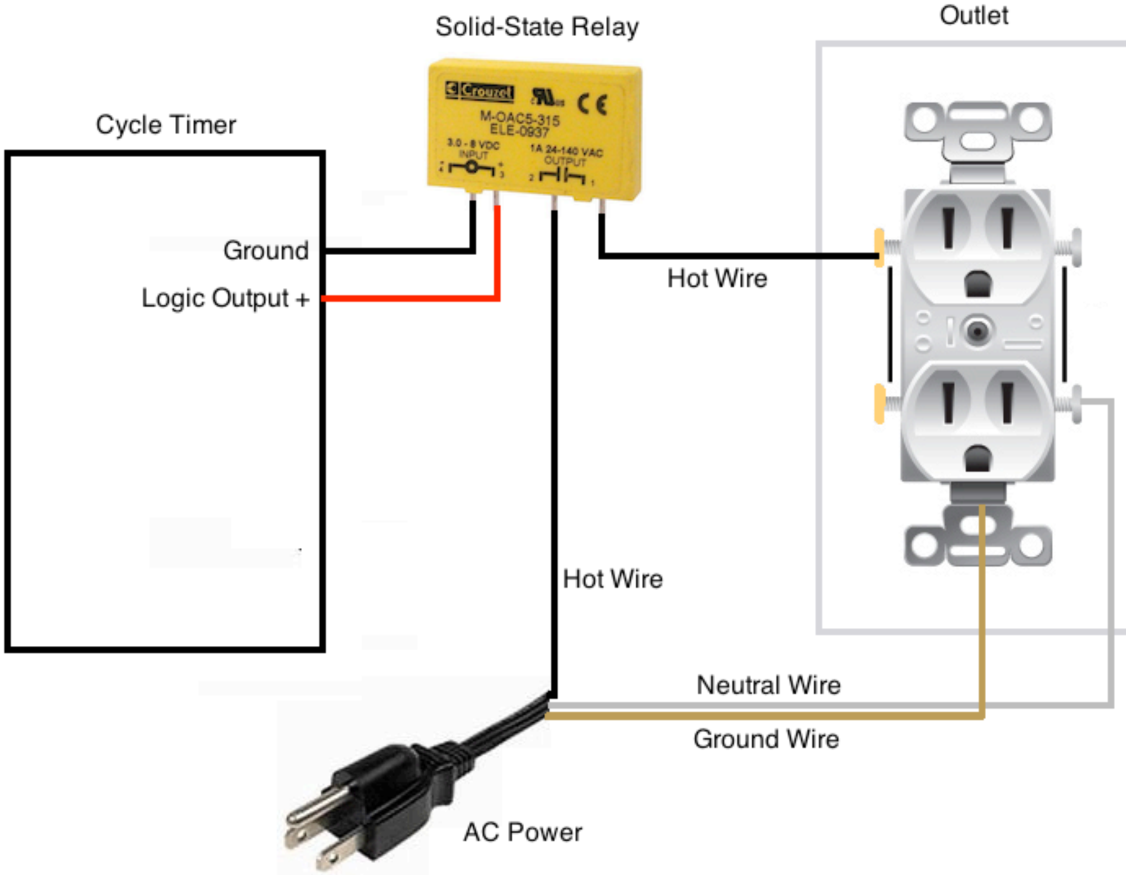

Figure 4-6: Outlet Wiring Logic

4.2. Solar Panels

Solar panels can be used where electricity is not available. This allows the user to place the Aquaponic or Aeroponic system nearly anywhere.

The solar panels required for a system varies depending on how large the system is. The larger the system the more solar panels are needed. The greatest demand on electricity is the water pump and heater.

Solar can also be used as a backup system if the main electricity goes out. This is very helpful because without a working water pump the plants can die very quickly, especially in an Aeroponics system.

For solar power the required components are solar panels, battery, charge control, and an inverter.

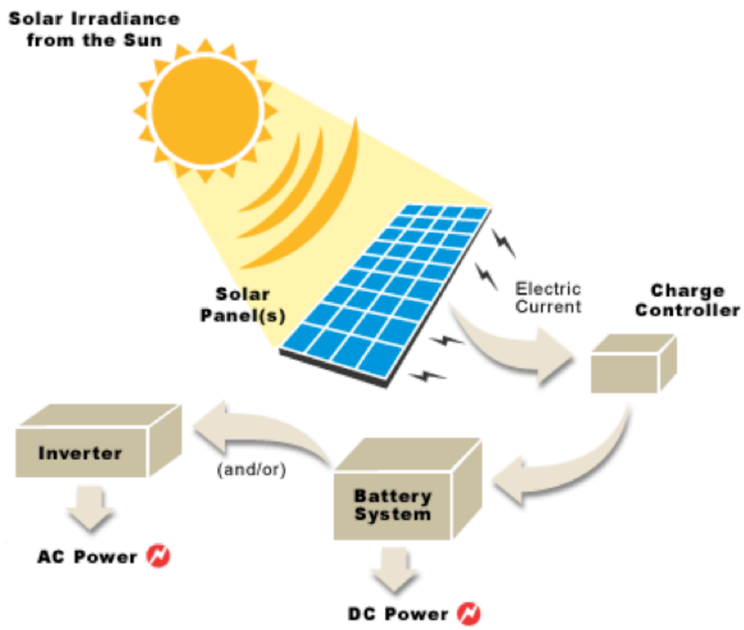

Figure 4-7: Solar Panel System

4.3. Types of Systems

The two types of grow systems below are the Aquaponics and Aeroponics systems. The major difference is the use of fish compared to liquid nutrient.

4.3.1. Aquaponics

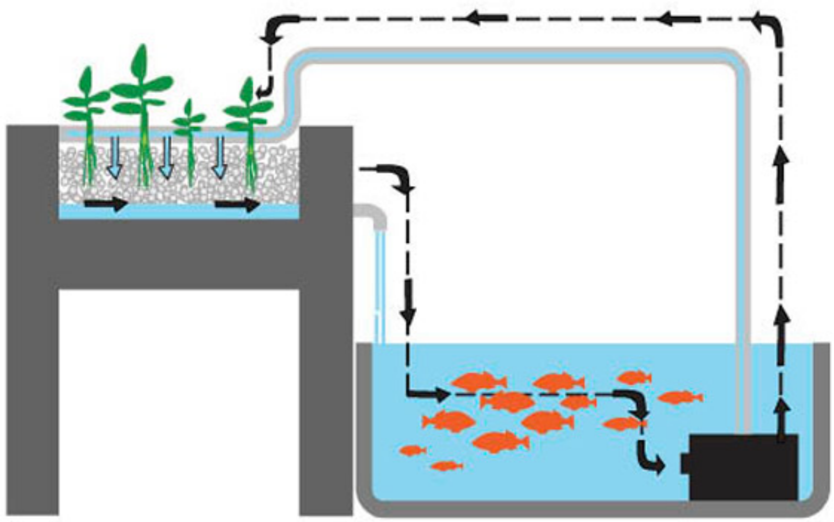

Figure 4-8: Basic Aquaponics System

The fish reservoir water is pumped into the grow bed and drained back into the reservoir. The waste is converted into nitrogen by the bacteria and the plants use the nitrogen to grow. The plants nitrogen uptake "cleans" the water and the water is returned to the fish in a closed loop system. This design is considered sustainable because the system continuously produces food while not depleting or causing harm to this world. Below are four reasons to why Aquaponics is considered sustainable:

1. The waste from the fish is used to feed the plants
2. The water is re-used in the re-circulating system
3. Continuous organic fertilizer
4. Increases local food production / economy, and reduces food transportation

There are several advantages and disadvantages with an Aquaponics system, which are listed below.

Advantages:	**Disadvantages:**
Closed loop system (no water changes)	Maintaining a balance between fish and plants
Minimal water consumption	Water Heater (if in cold areas)
Nearly no nutrient is added	Large amount of grow medium required
No weeds or pest	Weight of the system
Small water pump	
Harvest fish for food	

On the advantage side: A closed loop system is what sustainability is all about. No longer is the water or nutrient being dumped after depletion. Rather the water is re-circulated leading to minimal water consumption. The nutrient is the fish waste and therefore the grower does not need to add any nutrient to their plants in which can save a lot of money. Because the system is no longer in soil or on the ground there are nearly no weeds or pest. This makes growing much easier to maintain and clean. The small water pump is also an advantage because the water needs to be circulated constantly. The smaller the pump the less amount of energy is used and therefore a smaller solar system would be adequate. The end result is both fresh plants and fish for food.

On the disadvantage side: An Aquaponics system is a balanced system between both fish and plants. And this can be difficult to maintain because many plants prefer a pH around 6.8 and cooler temperatures around 65 degrees Fahrenheit. While fish like Tilapia prefer a higher pH of 7 or 8 and a temperature of 70-75 degrees Fahrenheit. The limitation is the plants and fish cannot get exactly the conditions they each strive for. But the balance in-between what both fish and plants desire is what the system should run at. If the system water is too cold the fish or plants can suffer greatly and may need a water heater to maintain desirable conditions. The grow bed should be at least half the size of the reservoir. This means that in a larger system you are going to need a considerable amount of grow medium in which can cost and weigh a lot. A grow bed size of 4ft x 10ft x 1ft can weigh up to 2,000 lbs.

4.3.2. Aeroponics

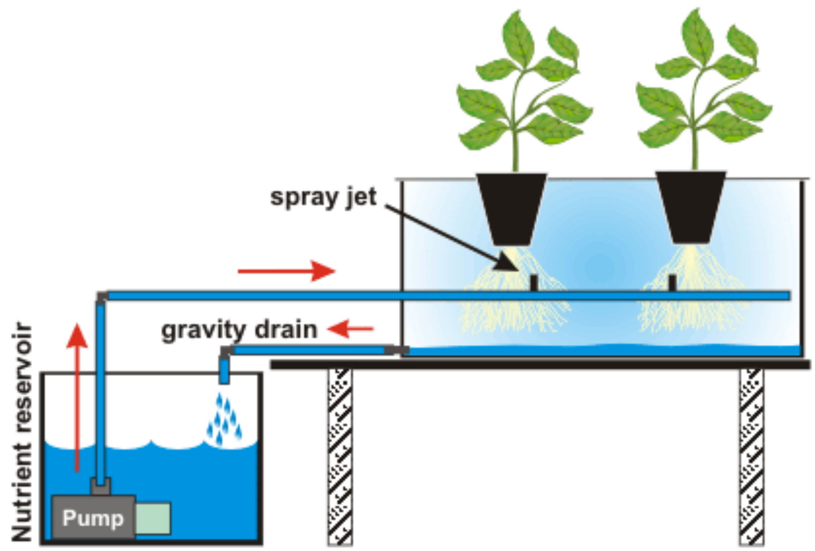

Figure 4-9: Basic Aeroponic System

The nutrient rich water in the reservoir is sprayed onto the plant roots on certain timer intervals. The excess water in then returned back into the reservoir to be used again.

There are several advantages and disadvantages with an Aeroponics system, which is listed below.

Advantages:
Water is re-circulated
Very minimal water consumption
Plants have a lot of air at the roots
Minimal usage of nutrient
Small reservoir required
Speed of growth and increased size of plants
No weeds or pest
Very minimal grow medium

Disadvantages:
Large pump needed
Nutrient / reservoir change
Pump failure
Air pump (optional but recommended)

On the advantage side: In Aeroponics the water is sprayed directly onto the roots and then re-circulated back to the reservoir. This minimizes the amount of water needed to grow plants. Because the water is concentrated to only spray the roots in a closed tube or box there is very little evaporation or wasted water. According to NASA's report Spinoff, "Aeroponics method can reduce water usage by 98 percent, fertilizer usage by 60 percent, and pesticide usage by 100 percent, all while maximizing their crop yields by 45 to 75 percent." (Spinoff, 2006, p. 67). This means that the nutrient reservoir can be rather small compared to the size and amount of plants that can be grown. This was the desired method of growing plants especially where water is scarce.

On the disadvantage side: An Aeroponics system uses the benefit of minimal water consumption while optimizing plant growth but there are drawbacks to the system. One major issue with an Aeroponics system is the issue with failure of the pump or electricity. Because the plants have nearly no medium (roots in the air), the plants can dry out and die very quickly. This is why a solar backup system is strongly recommended. In an Aeroponics system the water pump has to be relatively large because the high pressure is needed to micro spray the roots. This means the electricity demand is greater and a larger solar backup system will be needed. Other issues are with the water changes. If the reservoir's pH or nutrient levels get out of balance a water change is necessary.

4.4. Types of Grow Mediums

From Table 4 below, six grow mediums were compared: Gravel, Sand, Lava Rocks, Rockwool, Hydroton (clay balls), and Perlite.

	Cost	Weight	pH Impact	Water Retention	Dust/Debris	Availability
Gravel	Low	High	Possibly	Lowest	Needs Initial Rinse Only	Common
Sand	Low	Highest	Possibly	Low	Possibly	Common
Lava Rock	High	Medium	No	Medium	Needs Initial Rinse Only	Uncommon
Coir	Medium	Lowest	Yes	Medium	Yes	Common
Rockwool	Medium	Low	No	High	No	Uncommon
Hydroton	High	Medium	No	High	Needs Initial Rinse Only	Uncommon
Perlite / Vermiculite	Low	Low	No	Medium	Perlite Needs Initial Rinse	Common

TABLE 4-4: GROW MEDIUM COMPARISON

Four grow mediums were compared: Hydroton (clay balls), Gravel, Lava Rock, and Sand. Hydroton or clay balls are the most commonly used grow medium because they are pH neutral and have high water retention. Gravel has a naturally high pH and the lowest water retention, which makes it non-ideal for Aquaponics. This is because one of the issues faced with Aquaponics is the high pH. With a high or low pH plants are unable to absorb the proper nutrients needed.

Figure 4-10: Types of Grow Mediums

4.4.1. The pH and Nutrient Uptake

The pH is the measurement of how many hydrogen ions are present in the water. This can be measured with a pH meter or strips. This is probably the most important measurement to watch and maintain.

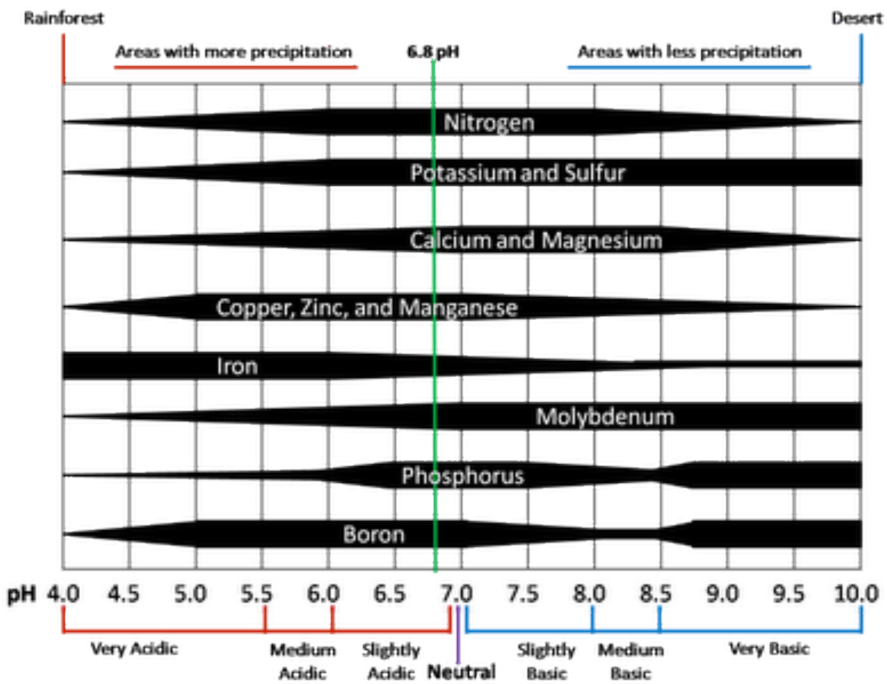

Figure 4-11: pH vs. Nutrient Uptake

From Figure 4 above, plants can only absorb certain nutrient at certain levels of pH. For example, iron cannot be absorbed above a pH of 8.0 (basic), which the plants can suffer severely from. Although, there may be plenty of iron available in the water, the plants are unable to uptake the iron unless the pH is in range. The same goes on the low or acidic end of the pH scale. This is why a neutral pH of 7.0 is ideal for optimal nutrient uptake.

4.4.2. Parts Per Million (ppm) and Electro Conductivity (EC)

Parts per million (ppm) is the measurement of the concentration of nutrient in the water. One ppm is equivalent to 1 milligram of substance per liter of water (mg/l) or 1 milligram of substance per kilogram soil (mg/kg). In other words, ppm is a way of measuring how much nutrient concentration is in the water. If the ppm is too high, then the plants can burn. If ppm is too low, the plants don't have enough nutrients to grow optimally. For most plants a ppm of 1200 is ideal. Although, some plants can tolerate a higher ppm without signs of stress, 1200 is a safe level.

PPM to EC Conversion Chart					
PPM	EC	PPM	EC	PPM	EC
70	.1	560	.8	1050	1.5
140	.2	630	.9	1120	1.6
210	.3	700	1.0	1190	1.7
280	.4	770	1.1	1260	1.8
350	.5	840	1.2	1330	1.9
420	.6	910	1.3	1400	2.0
490	.7	980	1.4	1470	2.1

TABLE 4-5: PPM TO EC CONVERSION CHART

Figure 4-12: Hanna Combo pH/EC/PPM/Temp Meter

In Aquaponics, the measured ppm is around 500 ppm and this is just fine. This is because organic nutrient have a very low conductivity of organic nutrient particles. In an Aquaponics system the ppm may read low, but this is because the system has a large amount of organic nutrient, which is hard for the meter to read. The low ppm readings in an Aquaponics system are sufficient for optimal growth.

Electro Conductivity or (EC) is the measurement of nutrient concentration in water. This is a direct correlation to the ppm scale. Depending on the company who makes the meter the conversion factor can differ. This is why most people refer to the EC scale rather than the ppm scale. An EC scale of 0.5 relates to a ppm of about 350, which is common in many Aquaponics systems.

4.5. The Bell Siphon or Auto Siphon

This is a method where the ebb and flow system is created through a siphon. The Ebb and Flow means that the water is flooded into the grow bin and then drained back to the reservoir. This is a very popular type of system because the roots get drenched in water followed by a dry cycle to provide air to the roots. The bell siphon is a unique way of creating an Ebb and Flow system because the water pump runs 24hrs a day while the water is still being flooded and drained based on the physics of water flow.

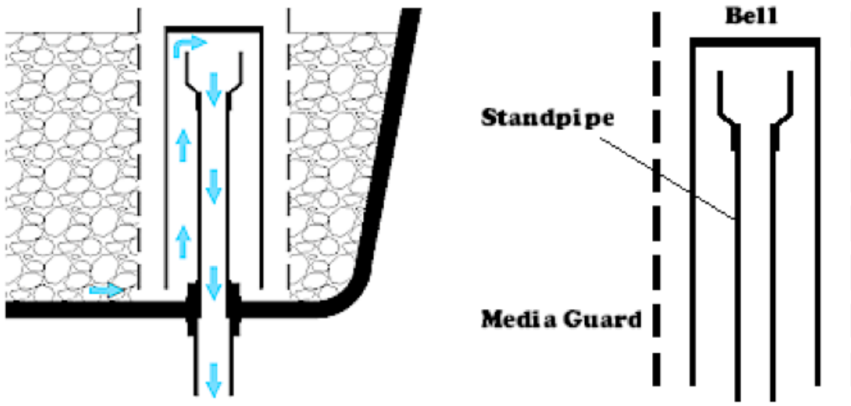

Figure 4-13: Bell Siphon or Auto Siphon

4.6. The Nitrogen Cycle

Natural Fish Cycling (Using Fish)

The bacteria Nitrosomonas convert the ammonia into nitrites. This conversion causes the ammonia to fall as the nitrite rises. The nitrite is still very harmful to the fish. Finally the nitrite is converted into nitrate by the bacteria called Nitrobacter. This is now "safe" for the fish. The completed cycle means that the ammonia and nitrites parts per million or (ppm) are at zero and only the nitrates are present. This means that the two bacteria's are working well and your fish are safe. The nitrate is the nitrogen that the plants can absorb and use. As the conversion from ammonia to nitrate continues the nitrogen available goes up. And the plants use up the nitrates in which "cleans" the water for the fish. So in the end of the cycle the water is returned as clean and ammonia free.

Fishless Cycling (Adding Ammonia without fish)

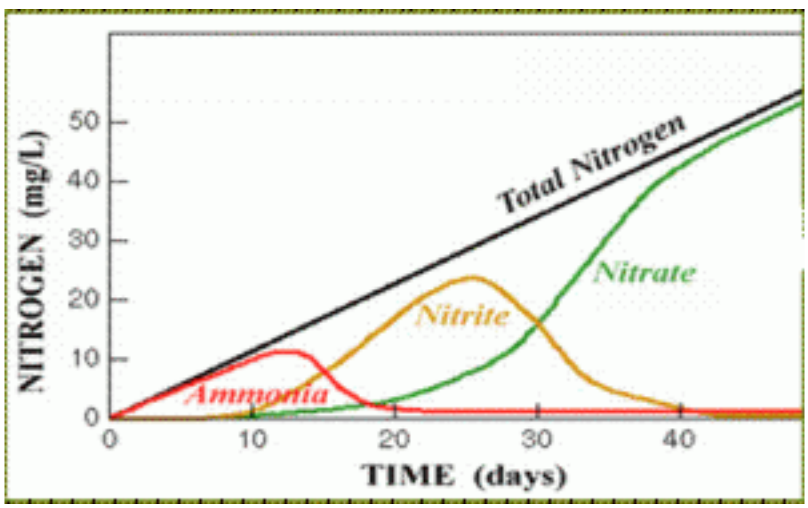

Figure 4-14: Nitrogen Cycle

5 Project Design Work

5.1. Aquaponics

Figure 5-1: 40 Gallon Reservoir

Figure 5-2: Hydroton Clay Pellets 50 Liters

Figure 5-3: 20 Gallon Grow Bin

Figure 5-4: Auto Siphon

5.2. Aeroponics

Figure 5-5: Magnetic Drive Pump 550 GPH Water Pump

Figure 5-6: 12x Micro Sprayer 360°

Figure 5-7: 6" PVC Pipe

Figure 5-8: 5 Gallon Bucket

Figure 5-9: General Hydroponics Nutrient: Grow, Micro and Bloom

5.3. List of Parts

5.3.1. Aquaponics

Water Pump (100 GPH)	Fish (Comet Goldfish or Tilapia)
Air Pump (Air Stone)	Sensor (ppm, pH, and EC)
Water Heater (Temperature)	Test Kit (ammonia, nitrite, nitrate)
Reservoir (40 Gallon)	Bacteria Supplement (Optional)
Rubber Maid Tub (10 Gallon)	Auto Siphon (Bell Siphon)
Hydroton Balls (1 Bag)	Nutrient (Seaweed Extract)
Water Tubing (3/4" x 3ft)	Bulk Head
PVC (1/2", 3/4") x 10ft	Light Proof Cover

TABLE 5-1: AQUAPONICS BASIC COMPONENTS

5.3.2. Aeroponics

Water Pump (550 GPH)	Nutrient (General Hydroponic)
Cycle Timer (On/Off Times)	PVC (6" x 6ft Schedule 80)
Air Pump (Air Stone)	PVC (1", 3/4") x 10ft
Hydroton Balls (1 Small Bag)	¼" Tubing (25ft)
Water Heater (Temperature)	12x Micro Sprayers (360 deg.)
Reservoir (5-10 Gallon)	6x Basket Pots (3")
Hole Saw (3")	2 Rubber End Caps (6")

TABLE 5-2: AEROPONICS BASIC COMPONENTS

5.3.3. Bio-Filter

Water Pump (50 GPH)	Bucket (5 Gallon)
Gravel	3/4" Tubing (4ft)
Sand	Bulk Head
Filter	Light Proof Cover

TABLE 5-3: BIO-FILTER BASIC COMPONENTS

5.3.4. Cycle Timer

555 Timer (NE555P)	LED (Red and Green)
2x Counter Chip (CD4020BE)	2x Rotary Switch
D Flip-Flop (MC14013BCP)	2x LED Holder
Resistors	Bread Board
Capacitors	9v Battery
Diode, Zener Diode	Solid State Relay (DC to AC)
Outlet Box with Cover	Wires (18 and 12 Gauge)
Outlet	PVC Electrical Conduit

TABLE 5-4: CYCLE TIMER BASIC COMPONENTS

5.4. Bio-Filter

Composition – Made of rocks, sand, and stones. The bacteria need a place to live and colonize. The bacteria that live in the bio-filter are the ones responsible for converting the ammonia into nitrate.

Light Proof Cover – The reason it needs to be light proof is because you don't want to grow algae or mold. Because algae are plants, algae will use the nutrient and oxygen in the water. This causes the fish to be deprived of oxygen in the water in which can cause damage to the gills and health of the fish. Without adequate oxygen in the water the fish will die. This is why we add air stones into the fish aquarium to ensure there is always enough oxygen present.

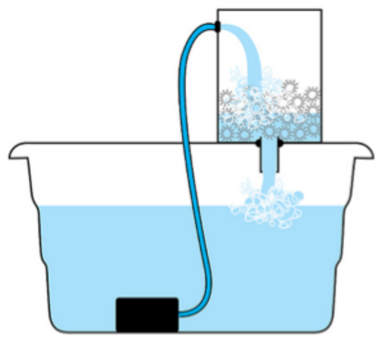

Figure 5-10: Bio-Filter

Bacteria – The fish waste is ammonia, which is very harmful to the fish and needs to be either converted or taken out of the system. The bacteria Nitrosomonas convert the ammonia into nitrate, while the bacteria Nitrobacter converts nitrite into nitrate. (Aquaponic Source, 2012) The plants then use the Nitrate as a source of nitrogen.

Water Pump – The pump for the bio-filter can be small. There is no backpressure so a water pump of 50 GPH is fine. This pump will run 24hrs a day, pumping water into the bio-filter and returning back to the fish tank.

5.5. Data Table

5.5.1. Aquaponics Nitrogen Cycle

Fish Reservoir in Aquaponics System	pH (range)	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	ppm	EC	Temp. °F	Temp. °C
~ 1 week old 3/7	8.4	0.15	0.2	0	608	0.82	63.5	17.5
3/14/12	8.1	0.4	0.25	1	730	0.94	62.8	17.1
Changed (1/2) the water after test above was taken. (4-gal) from inside aquarium rest from garden hose								
After change 3/14/12	7.6	0.3	0.2	5	500	0.8	62.6	17
3/18/12	8.3	0.2	0.17	20	620	0.9	62.8	17.1
3/23/12	8.4	0.1	0.1	40	673	0.95	62.2	16.8
3/26/12	8.3	0.1	0.1	70	682	0.96	62.4	16.9
3/27/12 **Added 50 Goldfish. Also adding ~ 1 once of Seaweed Extract once a week**								
3/30/12	8.3	0.1	0.1	100	704	0.97	61.9	16.6
4/2/12	8.3	0.1	0.1	105	712	0.98	70.0	21.1
Added pH Down by GH lowered pH from 8.3 to 8.1 (reducing by .2 everyday until 7.0 is reached)								
4/5/12	8.1							
Added pH Down by GH lowered pH from 8.2 to 7.9								
4/7/12	7.9				700	0.97		
Had to do a half water change due high nitrite level, caused by pH down? (Citric acid)								
4/8/12	8.1	0	5	100	705	0.97	51.4	10.8
4/8/12	7.8	0	0.5	100	640	0.88	59.0	15
4/12/12	8.3	0	0.15	40	570	0.83	58.1	14.5
4/14/12	8.3	0	0.15	35	580	0.85	60.8	16
4/16/12	8.4	0	0	40	666	0.92	68.0	20
1/18/12	8.4	0.2	5	60	660	0.92	66.2	19
4/18/12 **half water change due to increase in ammonia and nitrite**								
4/19/12	8.3	0.1	0.15	30	550	0.81	66.2	19
4/22/12	8.3	0	0	35	560	0.81	68.0	20
4/26/12	8.2	0	0	40	600	0.83	61.3	16.3
4/29/12 **made bio filter and tank light proof to eliminate algae growth**								
4/30/12 **Added 5 gallons of R.O. Water (pH 6.8)**								
5/2/12	7.9	0	0	30	592	0.82	61.2	16.2
5/6/12	7.9	0	0	30	590	0.82	60.8	16
5/15/12	7.8	0	0	20	585	0.81	62.6	17
5/22/12	7.7	0	0	15	580	0.81	62.8	17.1
5/31/12	7.5	0	0	5	575	0.80	64.4	18

TABLE 5-5: AEROPONICS NITROGEN CYCLE

5.6. Types of Fish

In Aquaponics, many freshwater fish can be used, but the most popular are the Tilapia, Trout, Carp, Goldfish, Catfish, and Perch. These fish are considered the most "hardy" meaning they can handle temperature and pH fluctuations better other fish. The most widely used fish in Aquaponics is the Tilapia. This is because not only are they eatable, but are also the hardiest and quickly growing fish.

Carp

Goldfish

Perch

Trout

Tilapia

Catfish

Figure 5-11: Types of Fish

5.7. Types of Plants

Plants that work well in Aquaponics are "nitrogen-loving" plants. This is because the ammonia converted into nitrate creates a nitrogen rich water source for the plants. There are many types plants that are ideal for this type of environment including Lettuce, Spinach, Mizuna, Tomato, Basil, and Parsley. The list is long and not very limited making this type of grow system ideal for a range of plants.

Lettuce

Spinach

Mizuna

Basil

Parsley

Tomato

Figure 5-12: Types of Plants

5.8. Cycle Timer Final Design

Figure 5-13: Figure 28: Cycle Timer

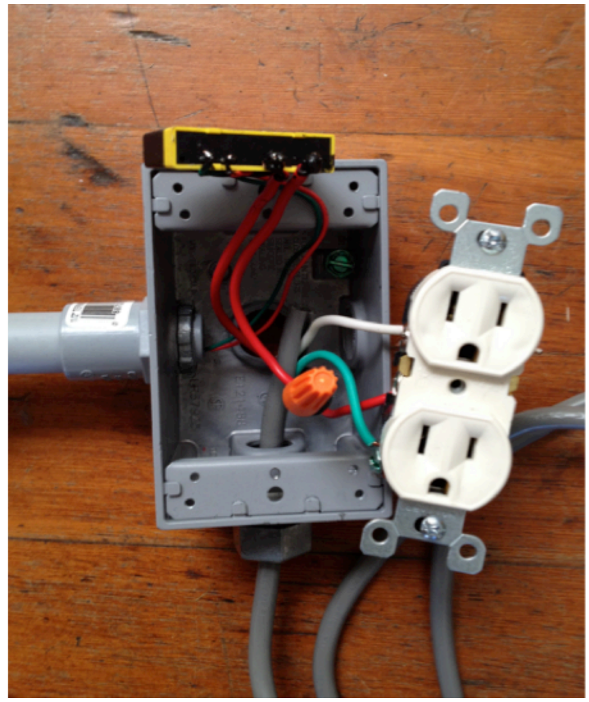

Figure 5-14: Outlet

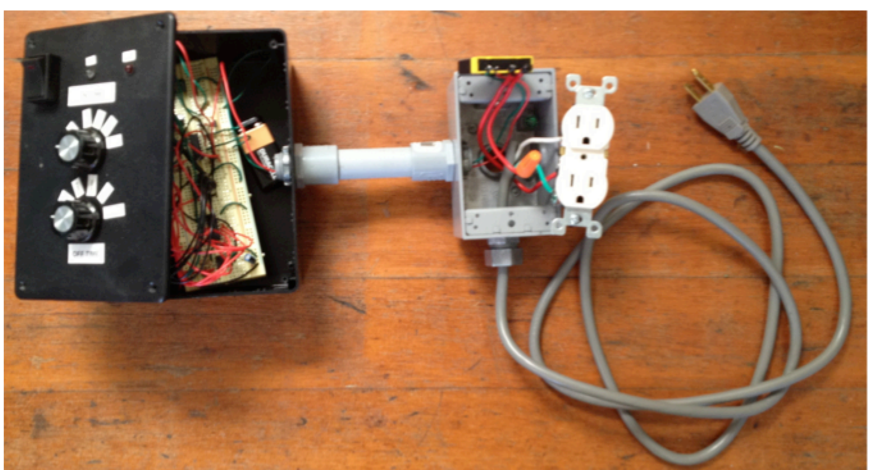

Figure 5-15: Cycle Timer and Wiring

5.9. Grow System Final Design

Figure 5-16: Montage of the System

5.10. Aeroponics System (SketchUp)

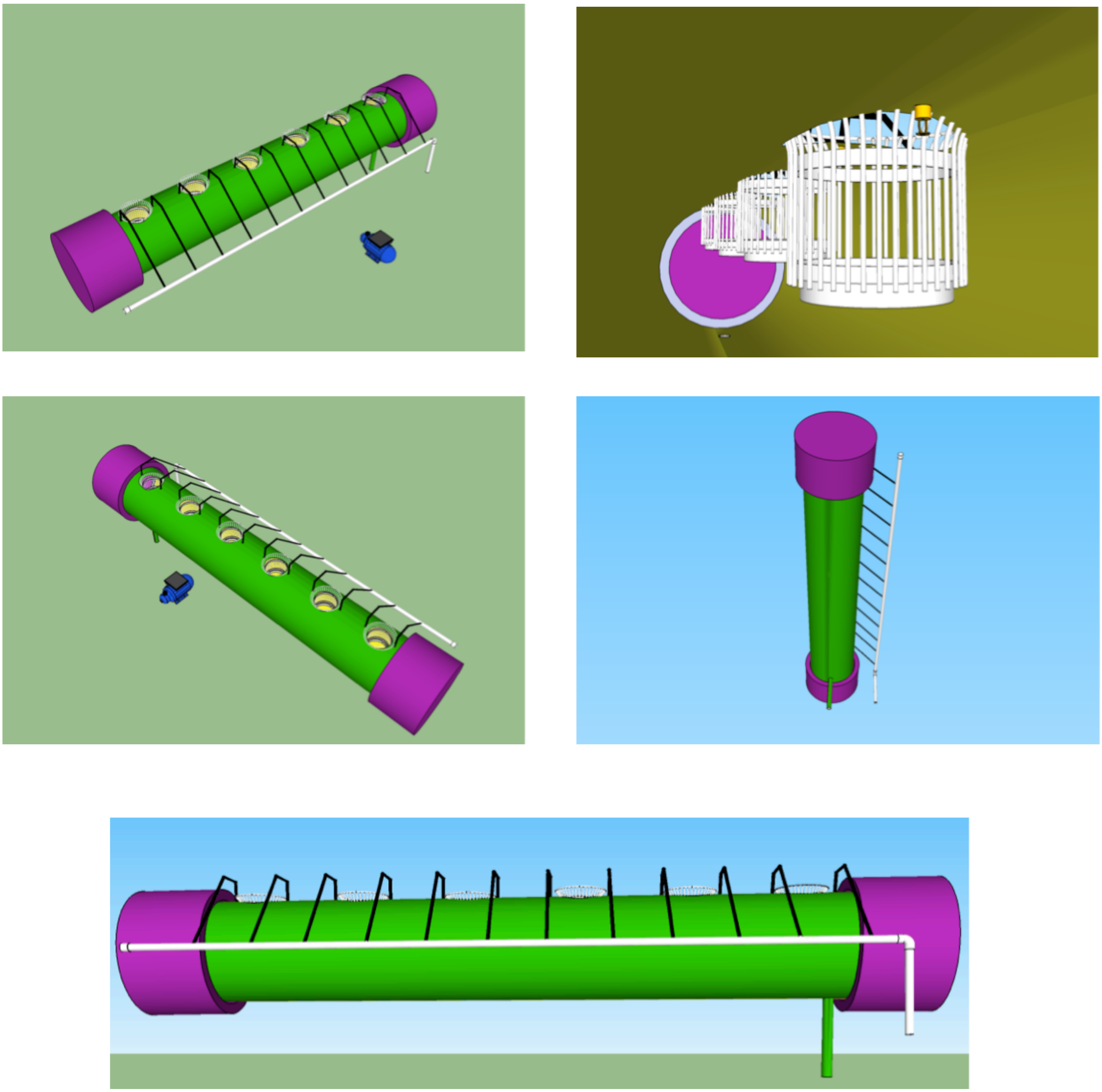

Figure 5-17: Aeroponics Grow System Design

5.11. Conclusions and Results

The ability to grow sustainable plants and fish for food are a possibility throughout the world. With the reduced usage of water to provide food where water is scarce is a goal and a reality. Through Aquaponics and Aeroponics the future of providing food in a sustainable manner is possible. Aquaponics presents both fish and plants grown in balance with each other as nature intended.

The cycle timer is required in an Aeroponics system to provide the proper feeding schedule to obtain optimum growth and size. As plants grow and mature they are going to require different feeding intervals. A cycle timer is the ideal electrical component to accomplish the plants needs.

NASA is a large contributor to this type of system with their space program and future goals of growing food in space. Water one of the most important resources on earth and only 3% of our water is fresh water. By new means of growing plants, we are able to maximize the food production while using the least amount of water. The future exploration for technology advanced growing systems will be a major strive in solving food shortages.

5.12. Bibliography

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6 Senior Project Analysis

6.1. Summary of Functional Requirements

My project is an Aquaponics / Aeroponics system with a cycle timer design implemented. This project demonstrates the ability to grow plants with nutrient and fish. A cycle timer was built and designed to be used in this grow system. This timer is in control of the water schedule based on the plants needs. The cycle timer uses the DC battery power to enable the switching logic of the solid-state relay to "open" and "close" the AC outlet. The water pump is then plugged into the AC outlet and is controlled by the cycle timer ON/OFF intervals.

6.2. Primary Constraints

In this Project there was several difficulties with creating a balance between the fish and plants. You need to make a naturally balanced system for both. This includes the pH, parts per million (ppm), and water temperature. The development of beneficial bacteria in the grow bed was the key component in growing plants successfully in an Aquaponics system. In the design of the cycle timer there were challenges in designing the appropriate ON/OFF timer intervals. Also, the design work for the structure of the timer was a challenge because of wiring codes and regulations. I considered necessary to make the product safe and user friendly.

6.3. Economics

The basic electronic components include the low cost integrated circuits or (IC's) chips. These chips are very powerful and useful and can be found in nearly all electronics. The cycle timer also includes a standard 9V battery, which can easily be replaced when required.

When using solar the input energy comes from the sun to run the water pump and air pump. The cost of the solar system will vary depending on the size of the Aquaponic/Aeroponic system. The consumer will have to pay for what type of system is desired. Using solar will save you money, by converting the suns energy into usable electricity, but the initial solar panel setup is costly. A small complete 55Watt solar system kit cost around $300. Currently in San Luis Obispo, CA the average cost of electricity is $0.18 per kilowatt-hour. This means that an Aquaponic system running 24hrs a day cost about $18 per year. An Aeroponics system cost about $28 per year to operate. These costs are calculated based on an air pump (5watts), a 550 GPH water pump (50watts), and a 100 GPH water pump (6watts). The solar system would take about 10 years before the costs are offset.

The ability to grow your own plants and fish for food can reduce the cost of living. The benefit is the locally grown organic food is grown without any pesticides, herbicides, or preservatives. By growing your own food in this type of system, you are no longer relying on the markets or stores. The other benefit to this system is the reduction in water used to grow the plants. By saving water you are in turn saving money. Water is so important in this world and only 3% of Earth's water is fresh water. Many countries around the world do not have clean available water. The Aquaponics system is an alternative way of growing that can provide countries around the world with a sustainable food source. I would like to see this system run at a commercial level to help provide food and knowledge to other countries. At commercial level, water usage can be reduced by 90% while food production is increased dramatically.

6.3.1. Bill of Materials

Amount	Aquaponics	Cost
1	40 Gallon Reservoir	$62.00
1	100 GPH Water Pump	$15.00
1	Air Pump	$15.00
1	Water Heater	$40.00
1	10 Gallon Grow Bed	$15.00
1	Hydroton Balls	$40.00
1	PVC	$10.00
1	Water Tubing	$5.00
1	Fish	$5.00
1	Auto Siphon	$5.00
1	Bulk Head	$5.00
1	Fish Food	$5.00
	Total	**$222.00**

TABLE 6-1: BILL FOR AQUAPONICS

Amount	Aeroponics	Cost
1	5 Gallon Reservoir	$6.00
1	550 GPH Water Pump	$80.00
1	Air Pump	$15.00
1	6" PVC Pipe	$35.00
1	Cycle Timer	$27.51
1	Water Heater	$40.00
1	PVC	$10.00
1	1/4" Tubing	$5.00
12	Micro Sprayer	$6.00
6	3" Basket Pots	$1.50
2	Rubber End Caps	$16.00
1	Hydroton Balls	$10.00
	Total	**$252.01**

TABLE 6-2: BILL FOR AEROPONICS

Amount	Cycle Timer	Cost
1	555 Timer	$0.13
2	Counter Chip	$3.00
1	D Flip-Flop	$0.68
4	Resistors	$2.00
3	Capacitors	$1.00
4	Diodes	$1.00
1	Zener Diode	$0.90
2	LED's	$2.00
1	Box	$8.00
1	Outlet	$2.30
1	Wiring	$3.00
1	Solid State Relay	$3.50
1	Power Cord	$3.00
1	9V Battery	$4.00
2	Rotary Switch	$8.00
1	Breadboard	$8.00
1	LED Holder Pack	$1.70
	Total	**$27.51**

TABLE 6-3: BILL FOR CYCLE TIMER

6.4. Environmental

The cycle timer contains electrical components that can pose a threat to the environment. Although, industries do their best to stay within regulations and safety there is always room for improvement. A problem can be seen in electronic waste or (e-waste), where a large numbers of electronic devices need to be processed and disposed of properly. Improper disposal can lead to serious health risks due to the lead, cadmium, and beryllium that can be contained in the devices. Currently industries are striving for safer chemicals and improved disposal methods for future electronic components.

The Aquaponics section of this project explores the positive effects it has on the environment. With the establishment of a sustainable organic food production system people are able to grow their own food without harming the environment. There is no by-product and no chemical waste. The system is a closed-loop system with a chemical balance of ammonia and nitrates between both the fish and plants.

6.5. Manufacturability

On a commercial basis, the manufacturability of the cycle timer, Aquaponics, and Aeroponics is feasible. Currently there are several large-scaled commercial Aquaponics systems that are producing fish and produce to the markets. In order to develop a commercial sized operation there are several factors that need to be considered such as land area and location. Leasing large areas of farmland is going to be costly.

Mass-producing the cycle timer will drive the initial cost of the product to drop. The initial cost of the cycle timer I developed is around $27, but on a commercial scale this price can be reduced. The reason I decided to build a cycle timer rather than buy one currently available in stores is the high cost. The cycle timer built by C.A.P. sells for around $90.

6.6. Sustainability

A large portion of this project was to create a way to grow sustainable organic foods around the world. The Aquaponics aspect of this project contains both fish and plants as a source of food. Not only is the grower able to harvest plants such as lettuce, spinach, and strawberries, but also the fish can be eaten. The most common grown fish is the Tilapia because of their "hardiness" and speed of growth. The fish waste is converted into nitrogen by bacteria and then used by the plants as nutrient. This creates a closed loop system where the grower is not wasting any water or nutrient. This is the most sustainable method of growing produce in my opinion.