UNIVERSITY OF PUERTO RICO
MAYAGUEZ CAMPUS
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Barefoot ELECTRONICS

Final Report

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Submitted to:
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Date: May 16, 2014
Course: INEL 5195 & ICOM 5047

Executive Summary

Aquaculture is the cultivation of both plant and animal, for human consumption or use in a natural or controlled environment. It exists to offset the decline and overfishing at sea due to scarcity and high demand. Our customer is Michael V. McGee, owner of Caribe Fisheries Inc. located in the Valley of Lajas, Puerto Rico [1]. His farm is dedicated to the breed of ornamental fishes and many other species such as Pangasius, Bass and Tilapia Filet [1]. He is confronting three major difficulties while manually breeding his crops. First of all, fish crop reproduction decreases throughout the months of November to February due to temperatures lower than 24ºC which produces a loss of $500 dollars a week for a total of approximately $8,000 dollars throughout the whole season. Secondly, when oxygen levels drop below 2ppm there is no system alerting the owner and in the meantime fish crops start to suffocate and die within an hour. Finally, a major concern to our costumer is that 70-75% of operational costs due to the use of water and air pumps 24 hours a day, translates into expenses of around $320 a month.

Our main objective was to provide our customer with an automated monitoring system and proper action following the event of a quality control metric deficiency. The deliverables for our project include a user interface that will let our customer control oxygen and temperature variables by setting their limits. This interface will also display real-time oxygen and temperature readings and will let the user know when the system is running out of battery. A control system is also included and is meant to receive input information of each one of the sensors (temperature and oxygen) and with the given information it should restore temperature levels by opening the heater and drain valves and closing them accordingly, also to restore oxygen levels it should turn on the air pump and open the tap water valve accordingly to actively replace the tank's water. It is estimated that by controlling the use of these valves and the use of the air pump, operational costs can be reduced by a 40-50%. As an additional feature our system will provide up to 4 hours of backup energy system in the event of a power outage.

The major difficulties faced have been regarding the hardware side of the design. Design tradeoffs, component calculations, malfunctions and deciding between costs have proven to be very time consuming. While developing the design we have noticed that the GSM module was not entirely necessary, water level indicators and buttons for the user interface panel were also added and the Bluetooth was exchanged for an X-bee which deviate the solution for the best, from the originally proposed idea. All these decisions that have had to be made during the design phase have delayed our progress, because a change that is made to the hardware also affects the software design. While it was estimated that the design would be completed by February 21, 2014 it was actually finished by February 28, 2014. This has mostly delayed the process of ordering parts and the contingency measure taken was to buy parts that can be found in local stores here in Puerto Rico in order to start the implementation immediately.

The total costs for the project development were estimated to be $30,820.67. The parts and components costs are $780 and the total budget spent is 23,100.89. Meaning that by the end of our journey we managed to have 7,719.78 left from our initial budget even though some extra money was spent in parts due to hardware malfunctions and design tradeoffs.

Potential customers to our product are small aquaculture farmers on the rise here in Puerto Rico and in the United States. Of course our main concerns are here in the island which is what inspired this idea due to the fact that 85% of the seafood consumed here is imported. This project has the potential to give us the opportunity to boost aquaculture in the island and decline the dependency on imported goods by creating a more self-sustainable economy at least in the seafood business.

Contents

Introduction

Our Aquaculture Maintenance System was designed to provide small aquaculture farmers with a more effective way to use their available resources and at the same time enable them to handle the more problematic issues that directly affect their productivity, with hopes that the final product will result in an increase on the profits and a reduction on the amount of work involved in the process. Our costumer Michael V. McGee has to carry out practically all processes and tasks manually, meaning that he has indeed a substantial need for automated monitoring systems.

Therefore, our customer is not alerted when temperatures fall below 22ºC which affects fish crop reproduction throughout the winter and represents a total loss of $8,000 dollars throughout the whole period. He is also not alerted when oxygen levels drop below 2ppm and in the meantime fish crops start dying within an hour, but his major concerns are regarding operational costs since around $320 dollars are directed towards power consumption. Our system is unique in providing our customer with a system to monitor oxygen and temperature variables and providing him with an automated solution for these metrics. The customer will be able to choose oxygen and temperature limits to his preference and our control system will be in charge of restoring oxygen and temperature levels while making efficient use of valves and pumps to reduce power consumption and at the same time providing a backup energy system that could operate for 4 hours in the event of a power outage.

Each module was designed, implemented and tested separately to ensure proper functionality. Then the modules were integrated together to complete the whole system. The system was tested again to ensure successful integration. Success proved that the system was 100% completed. The prototype for the system was setup in the premises of the "Finca Alzamora" inside campus.

The aspects that will be presented and discussed in this document will be the design criteria and specifications for the system, methodology and a brief market overview. Also, the budget analysis will include final budget spent, a prototype sell price analysis in order to recuperate investment and residual budget. Lastly, a future work section will be included to analyze which aspects off the product can be enhanced.

Design Criteria and Specifications

Our project contains two main goals which were our cornerstone to our design. The user wanted to diminish power consumption and raise temperature during winter season. After some research and discussion with Mr. McGee, we established that the system must possess the following features. The ability of controlling the valves, to pour hot or cold water, thus increasing or lowering temperature accordingly, as well as the drain valve. Using sensors to provide real time readings gives us the control needed to use the air pump whenever it is required thus avoiding a 24/7 use, meaning less power consumption. This features were divided into three modules; the User Interface, the Main System and Power module. See **Appendix E** for detailed components calculations, power specifications and schematics.

Module	Parameter	MIN	TYP	MAX	Units	Notes	System Operation
Main System	VCC	2	3.3	3.6	V		The system is controlled by an MSP430FR5739 which routinely using timers for power efficiency, monitors water temperature and dissolved oxygen levels. If any of these two levels exceeds the limits the system will activate an unique response system that takes corrective action enabling hot water circulation, water pumps, and air pumps as needed. This main system will communicates via X-Bee RF module using IEEE 802.15.4 standards to a user interface box conveniently located in an accessible location for the user within 30 meters of range. Messages sent to the user interface box will indicate temperature, dissolved oxygen level, if the system is currently regulating any of the parameters and if the backup battery is running out of charge. This module will be powered by a power supply which is mainly connected to the grid, and that also provides a backup system in case of a power failure.
	VSS	-	0	-	V		
	Power Consumption	0.02	5.16	25.8	W		
	Temperature Sensor	-10	-	+85	˚C	±0.5 ˚C accuracy	
	Read Range	-55	-	+125	˚C	±2 ˚C accuracy	
	Oxygen Sensor Read Range	0	-	20	mg/L	±0.01 mg/L	
	Water Level Sensors	-	-	3.3	V		
		-	-	3.3	mA		
	Water Valves Operating Values	6	12	12	V	VDC	
		200	400	400	mA		
	Wireless Range	-	-	30	m	Indoors/Urban	
		-	-	90	m	Line of Sight	
	Storage Temp. Range	1	25	50	˚C		
User Interface	VCC	5	6	7.5	V		The User Interface Box will work by firstly asking the user for the parameters. Once set, it will send the values to the main system and then go to low power mode. While doing this the LCD will turn off. To change the parameters set, the user can press the up/down buttons at the same time. Once in this mode the user can press up or down to move between the values. When a low power signal or any other signal indicating severity is received the red led and buzzer will turn on. When the user presses the “alarm off button” the red led and buzzer will shut down but the LCD will initialize and display what produced the alarm. If the system is idle the user will be capable of seeing the sensor readings when he presses the on button. Always after 30seconds, the LCD will turn off automatically. Lastly a green led will be turned on while parameter regulation is been performed in the water tank.
	VSS	-	0	-	V		
	MCU	2	3.3	3.6	V	Output current: 6mA	
	LDO	1.2	-	37	V		
	LEDs	2	-	2.4	V	Input Current: 16-18mA	
	LCD	4.5	4.8	5	V	Operating I: 20mA	
	Push Buttons	-	3.3	-	V	Operating I: 1mA	
	X-Bee	2.8	3.3	3.4	V		
	Buzzer	3	3.5	5	V	Audible: 2kHz range	
	Power Consumption	-	13	-	mW	Active 1h/day	
	4 1.5V AA Batteries Life	-	1153	-	h		
	Wireless Range	-	-	30	m	Indoors/Urban	

Power Supply	Input Voltage	115	120	130	Vrms	60Hz	The power supply is composed principally by DC/DC converters of the buck type, their function is to step down the voltages coming from the electric utility, through a transformer and a diode bridge, and produce at the output the desired voltage levels. The power supply have the circuitry to charge a 12V Battery by a current of 1.5A and to use this battery to turn on the Air Pump, this pump can be also activated using the electric utility. A microcontroller is used to monitor the voltage and currents at the battery and decide when to turn on the pump after the proper signal is received by the main system. An H-Bridge inverter is used to source the Air Pump from the battery.
	Input Current	-	0.76	1	Arms		
	Output Voltage	-	12	-	V		
		-	3.3	-	V		
	Output Current	-	2	-	A	12V	
		-	1	-	A	3.3V	
	Battery Voltage	11.5	12	13.5	V		
	Battery Capacity	-	7.5	-	Ah		
	Battery Life	3	16	4800	h	System Active 5h/day	
	Power Capacity	-	45	50	W		
	Efficiency	75	88	90	%		

Software Specifications

This section intends to explain how the user interface hardware works based on the code behind it including interrupts, polling, low power mode status, and deviations.

As for the user interface box, the microcontroller will contain a timer which will turn off the LCD automatically to decrease power consumption. Information will be displayed when the user needs it to and will display for a minute after no action is detected. The MCU will be interrupt-based when dealing with the buttons except, when the user is entering information in which the MCU will be polling the buttons. This is done because the system should almost never be in the system menu. The other possible interruption to the MCU will come from the X-Bee module when data is received.

As a brief description of the X-Bee modules, they can be set in low power mode allowing for less power consumption. These devices are built setting easy communication between them; they can even make network meshes. The user interface box X-Bee will receive signals such as the alarm, values sensed by the equipment and regulating mode. If the system is in regulating mode a green led will be turned on to display when an action is taking place, if it is an alarm the buzzer and a red light will indicate a warning or problem such as the system not working properly or a low battery status. In the case where the user enters the range of values for the sensors for the first time or modifies them. The X-Bee module, found on the user interface box, will send the range values for the temperature and oxygen to the control system X-Bee for it to base its point of reference when deciding when to regulate. Detailed software design flowcharts, mockups, use cases and sequence diagrams can be found on **Appendixes G and H** respectively. Standards used may be revised on **Appendix C** along with details in regards to system specifications which include power consumption.

Methods and Approach to the Solution

Technical Approach

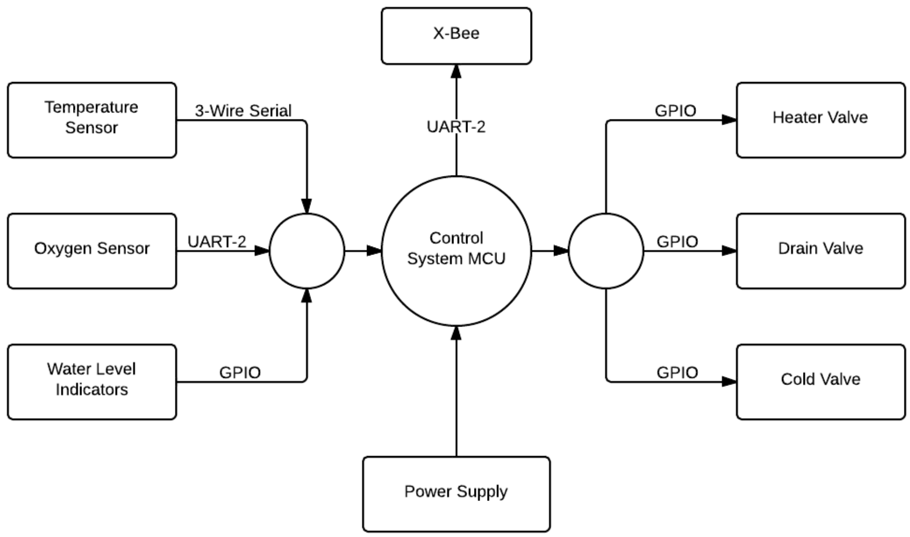

Fig. 1.0 System Level Block Diagram – Illustrates a system level view of the different modules and communication types that compose the physical structure of the final design.

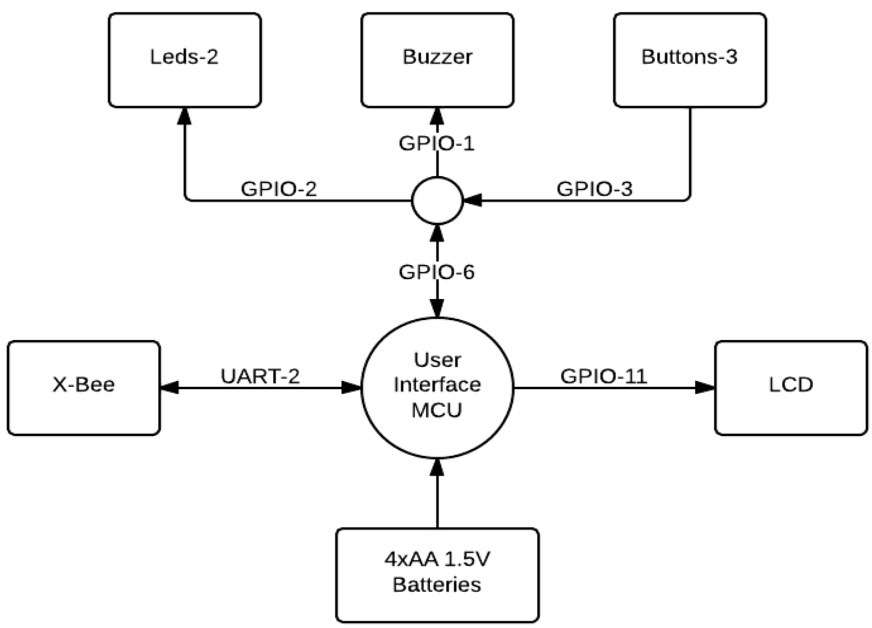

Fig 1.1 User Interface Diagram – Provides a detailed view of the user interface module including communication to a panel via Bluetooth(X-Bee).

Testing and Quality Control Procedures

The project objectives were approached and accomplished in the following manner:

- Designs were enclosed in separate modules
  - Oxygen sensor
  - Temperature sensor
  - Control System
  - User Interface (MCU/Bluetooth/Buzzer/LEDs/LCD Display)
  - Power Supply
  - Air pump, water heater and water valves.
- Individual modules were simulated to verify proper functionality
- Each module was tested individually before passing to the integration phase to ensure proper functionality. [Refer to **Appendix I** for detailed testing procedures]
- Integration of all modules for final design implementation.
- Testing and refining final design implementation.

This was the most effective way to approach the problem. By using individual modules and testing them there is less time spent troubleshooting and building the system, making sure there is more time invested on achieving improvement of the systems efficiency, personalized features and goals.

To ensure quality control measures only parts coming from the United States were ordered, most likely from known companies such as Texas Instruments, whose products are certified on QC metrics by Product Engineers before launching into the market. Ordering from outside of the United States can result in a shipping delay when the need for new or replacement parts arises also, the shipping might turn out to be more expensive.

Managerial Approach

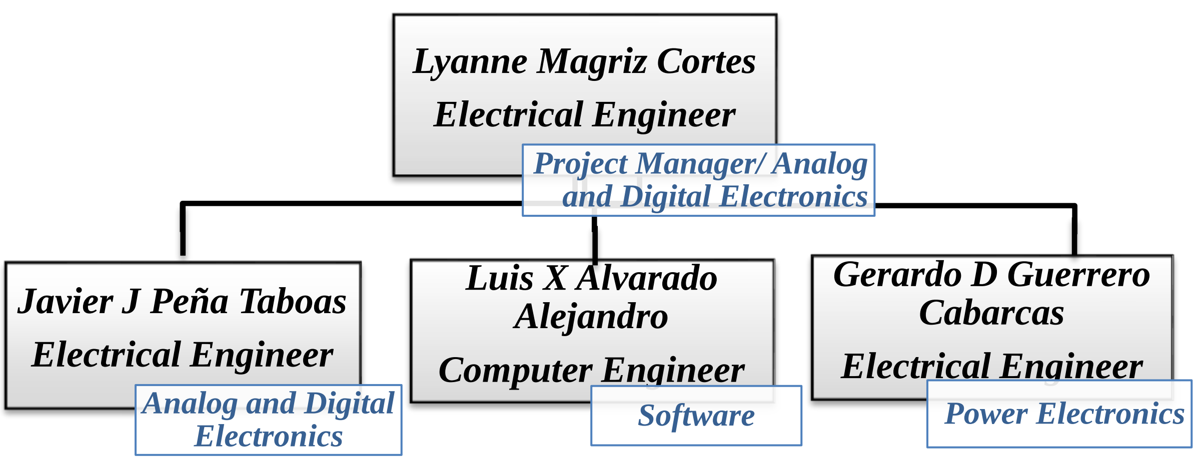

Fig 1.1 Managerial Approach Diagram

Team Meetings

Team meetings were held officially on the Capstone course laboratory.

- Mondays, Wednesdays and Fridays, from 9:30-11:30am and 3:30-6:30pm.
- Tuesdays and Thursdays from 10:30am to 3:30pm.

This gives a total of 5 work hours a day for a total of 25 hours a week.

Progress was tracked by the use of Microsoft Project, a project management application. This gave us the opportunity to collaborate and modify the project plan, while keeping in sync all team members. See **Appendix K** to find detailed Gantt Chart attached.

Team Member Organization

	Lyanne Magriz	***Javier J Peña***	***Luis X Alvarado***	***Gerardo D Guerrero***
Control Systems		✓	✓	
Software / User Interface			✓	✓
Power Electronics				✓
Instrumentation / Sensors	✓	✓		
Project Management	✓			

Table 1.0: Team Organization

Project Schedule – Milestones

Design

- ✓ Design Completion, Friday February 21,2014

Implementation

- ✓ Complete Modular Implementations, Friday March 14,2014

Testing and Refining

- ✓ Modular Testing Completion, Wednesday April 2,2014

Integration

- ✓ Complete System Integration and Final Testing, Monday April 21, 2014
- ✓ System Demo, Monday April 28,2014

Delivery

- ✓ Turn in Equipment and Parts, Wednesday May 14,2014

Market Overview

Current Client

The target users for our AMS are national small aquaculture farmers. These are farmers that have a gross income of about $250,000 or less yearly. The reason for this is because big aquaculture farmers have huge amounts of expensive equipment that similarly provide the same base functionality of the AMS device. Our task is not to force these big farmers to substitute their system with ours, but to help the small farmer with our affordable high level sensing device. The AMS will provide the solution to the starting or the veteran small aquaculture farmer needs to maximize their production efficiency while running on low electric power consumption, and keeping their fish safe and healthy.

Potential Client

Medium and large aquaculture farmers can be targeted as clients when the system has been solidified enough and the revenue has been enough to pursue to enhance the product with more features and more ample sensing functions. Also a system like this will require maintenance and customer support, this is why revenue is so important, generally speaking maintenance costs go up to 80% of the budget.

Our base system provides only readings for oxygen and temperature. Upgrades and system enhancements will make a more competitive product for the big aquaculture farmers both nationally and in the U.S.

Market Range

Our main market would be independent aquaculture farmers in Puerto Rico and the United States, who are launching in the aquaculture business and have the need for reliable, yet affordable automated maintenance systems. The census information available up to 2005 shows that there exist around 4309 aquaculture farms in the United States and 1847 dedicate themselves to breeding fish for consumption, other 358 produce ornamental fishes and the rest goes to sports fish, bait fish, and others [17]. In Puerto Rico up to the 1990 the census information available shows that there were 14 aquaculture farms established. Puerto Rico has a huge dependency on imported goods and this is why aquaculture needs a strong boost in the island [17].

Companies in the United States like NOAA fisheries maintain a well-organized system in which half the seafood eaten in the U.S. and abroad are produced through aquaculture [8]. It creates employment and meets with the increasing global demand for seafood. Being such a huge company, they possess the resources to purchase high end technologies.

Competition

There are similar products to the system we are proposing in the market, but although they provide means to track the oxygen, the ammonia and the PH they lack of a system to control this variables, therefore limiting its functionality to alert the user of any problem and provide a solution. The solutions that we provide to the problems that arise is what brings our product to an advantageous position. One example is the “IQ SensorNet 182”, this device can measure temperature, read dissolved oxygen, detect pH levels, conductivity, turbidity, potassium, nitrate, oxidation reduction potential (ORP) and ammonium [7]. It displays information on a digital display and sensors are easy to replace, just plug and play. However it does not include systems that help treat any problem that may arise. It is up to the user to make decisions using the information provided by the system. A system with similar characteristics as the previous mentioned is the ACQ110: Aquarium Controller Evolution by PENTAIR, this system also lacks automated action mechanisms to control the variables it senses [18].

Results

Technical Results of the project

All modules were successfully designed, implemented, proven to be entirely functional and integrated. Complying with the objectives established in the proposal a complete Aquaculture Maintenance System was developed able to provide the user temperature and oxygen readings, proper variable regulations, user interaction and control over the system, efficient use of electrical components to reduce power consumption and a backup energy system that lasts a minimum of 4 hours in case of a power outage.

Figure 1.1 – User Interface Box

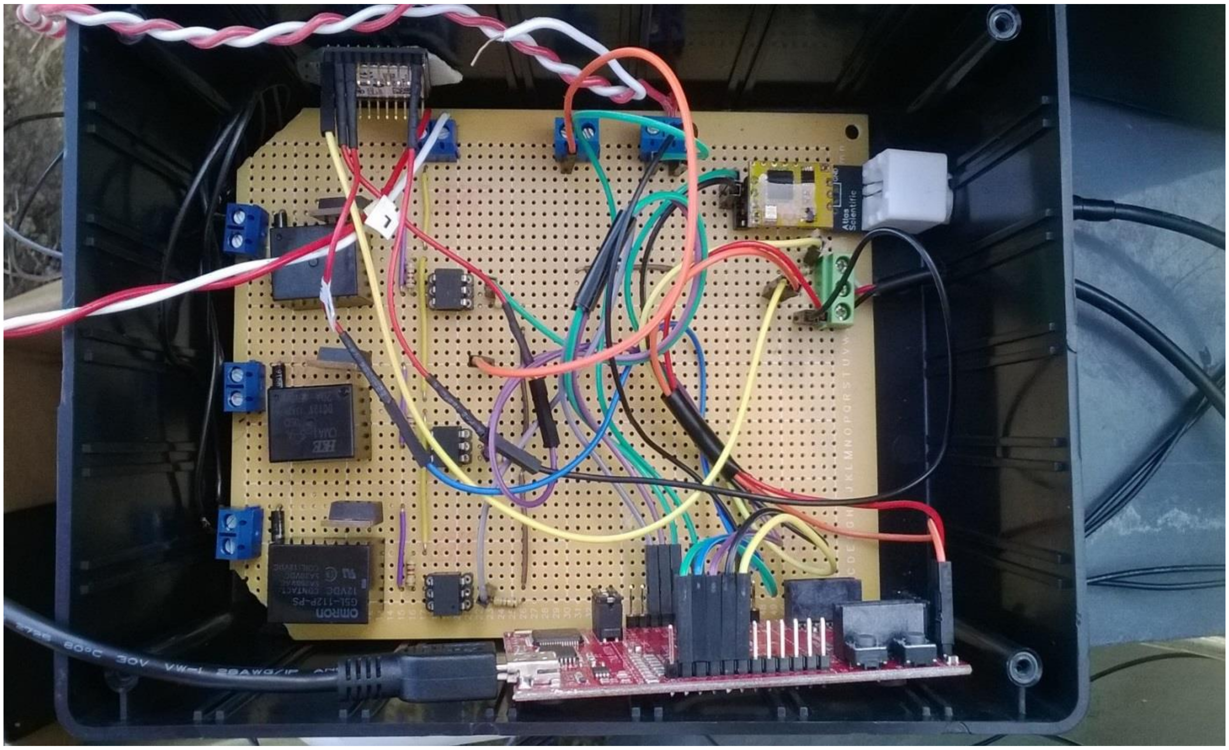

Figure 1.2 – Main Control System

Figure 1.3 – System Architecture

Ethical Aspects

Ethics is a very important part in mostly everything that is done. Especially in our case as we need to ensure that no misleading information is being provided to the farmer or there will be great consequences. Maintenance of the system and software updates is of essence in maintaining proper functionality and calibration of sensors. Also, we will disclose upon request, the algorithm used for regulation of oxygen and temperature conditions.

Legal Aspects

The legal aspects contemplated within the scope of this project were mostly to acquire permissions to perform experiments where animal's health and environment might be compromised. Also, more than just a quality control metric, proper encasing for electrical components resistant to humidity and water exposure must be ensured to keep the user's interactive experience safe and the system working properly to maintain fish crops in optimal conditions.

Environmental Aspects

As for environmental aspects the benefits that AMS brings is a reduction in power consumption, but most importantly a boost in the aquaculture industry that results in a reduction of exploitation and overfishing at sea. This helps create a more self-sustainable growing economy in the country since 85% of the seafood we consume is imported. As for the negative environmental impacts that it may cause is the incorrect disposal of electrical components once they have reached their usable life. If correct protocol is followed most of the components that work can be easily recycled to reduce the environmental impact.

Social Aspects

Society will be able to grow less dependence on imported goods therefore the processes for seafood will become less expensive for the seller as well as the consumer. We live in an island and it should be relatively easy for us to live from aquaculture compared to other countries that do so and are not actually completely surrounded by the sea as are we. Society needs a boost, but not only a growing idea, but an affordable one and this is what we aim to provide with our system.

Budget Analysis

Budget analysis includes labor costs per employee, overtime hours if any, fringe benefits, costs per parts and overhead expenses. Employees worked a total of 300 hours during the capstone period and the total spent in salaries for the four team members for a total of 1200 hours was $22,230.22 including fringe benefits. A total of $9,246 was estimated initially for overhead expenses and costs per parts ended up being around $780. This has left us with a total of 7,719.78 of overhead expenses left from the original budget of $30,820.67 which means we are still within budget. For more economic analysis details review **Appendix J**.

Resource Name	Type	Budget Type	Work hrs.	Standard Rate (Hourly)	Overtime (Hourly)	Total Cost	Social Security	Medicare	Retirement	Total - AB
Lyanne	Work	Labor	300 hrs.	$25.00	$38.00	$7,500	7.65%	1.45%	6%	$6,367.50
Luis	Work	Labor	300 hrs.	$23.68	$34.00	$7,104	7.65%	1.45%	6%	$6,031.30
Javier	Work	Labor	300 hrs.	$19.30	$27.00	$5,790	7.65%	1.45%	6%	$4,915.71
Gerardo	Work	Labor	300 hrs.	$19.30	$27.00	$5,790	7.65%	1.45%	6%	$4,915.71
Total			1200 hrs.			$9,258				$22,230.22

Table 1.1 – Salaries and Fringe benefits

Daily Labor Costs	$436.40
Component Prices	$780.00
Company Profit (30%)	$364.92
Installation cost	$200.00
Total Unit Cost	**$1781.32**

Table 1.2 – Unit costs

The system is estimated to be sold for the price of $1,781.32 including a one-time installation fee of $200, daily labor costs and component prices. After the first unit is sold unit prices are meant to go down because the heater must not be sold with every unit nor is the user interface box making the costs go down to $1,181.32 if the system is being installed with the rest, if not installation fees may apply. The client will recover his investment depending on how many tanks he has and/or is interested in automating.

Part Name	Part Number	Distributor	Manufacturer	Quantity	Cost/unit	Extended Cost
MCU-Experimental Board	MSP430FR5739	Texas Instruments Inc.	Texas Instruments Inc.	2	$35	$70.00
MCU-LaunchPad	MSP430G2452	Texas Instruments Inc.	Texas Instruments Inc.	1	$10	$9.99
DC2D Converter 3.3V	LM3940IT	Digikey	Texas Instruments Inc.	2	$1.75	$3.50
DC2DC Converter 5V	LM2931AZ	Digikey	Texas Instruments Inc.	2	$0.80	$1.60
Buzzer	COM-07950	Sparkfun	Cui Inc.	1	$1.95	$1.95
LED	COM-00533/COM-09650	Sparkfun	N/A	2	$0.35	$0.70
X-Bee WRL	WRL-08665	Sparkfun	Digi International Inc.	2	$22.95	$45.90
CMOS Digital Switch	TC74HC4066 APF-ND	DigiKey	Toshiba	4	$0.67	$2.68
Push Buttons	MB2411JW01-A-1A	DigiKey	NKK Switches	3	$6.36	$19.08
LCD	LCD-00255	Sparkfun	Hitachi	1	$13.95	$13.95
Capacitor	Assorted 100 pack	Digikey	Panasonic Electronics	1	$5.99	$5.99
Resistors	Assorted 100 pack	RadioShack	RadioShack	1	$4.99	$4.99
Relay	G5T-1A DC12	DigiKey	Omron Electronics Inc.	3	$1.26	$3.78
Diode + placas	1N4004	RadioShack	N/A	12	$1.5 +16	$28.98
Temperature Sensor	DS18B20	Sparkfun	Dallas Semiconductor	1	$9.95	$9.95
Oxygen Sensor	DOSAS	Sparkfun	Atlas Scientific	1	$192.95	$192.95
Water Level Indicator	LS7-Series Single Point Type 10 SW	GemsSensors	GemsSensors	2	$5.00	$10.00
40V N Power MOS	CSD18504KCS	DigiKey	Texas Instruments Inc.	3	$1.62	$4.86
Water Valve	3/4" Solenoid Valve	Value Direct	Solenoid Valves	3	$11.99	$35.97
Water Heater (80Gal)	Shower Heater	Home Depot	Home Depot	1	$69.95	$69.95
12V Battery	LC-R127R2P1	Digikey	Panasonic Electronics Inc.	1	$33.44	$33.44
Top Fin® Air Pump	AIR-8000	Petsmart	TopFin	2	$30	$59.98
Water Tank (300Gal)	10" Metal/Square	Dixon Rivera	N/A	1	$80	n/a
(55Gal) Blue Drum	23" x 35"/ 2" plastic caps	Dixon Rivera	Arizona barrels	1	$25	n/a
Plastic Box 5.9"x3.9"x2.36''	15882 BX	MPJA Online	N/A	2	$3.49	$6.98
Fish	GoldFish	Petsmart	N/A	10	$0.85	$8.50
Microcontrollers	MSP430FR5739	Ti	Texas Instruments	2	$70.0	$70.0
					Total:	$715.47

Table 1.3 - Component Costs

Conclusion

The project was a success with respect to software/hardware completion, power management and integration. All the modules stood together in order to make a stand alone system work accordingly to the already specified objectives. The method chosen to develop the prototype was “divide and conquer”. The User Interface, Main System and Power Supply were independently built and tested, making intercommunication complications at earlier stages of integration less probable. In the other hand, the approach we took in respect to building the prototype was to first build each module and later the system based on what we had learned during module implementation.

The prototype constructed is a viable way for small farmers to monitor their breeding system. It provides automation which simplifies the farmers work, as well as peace of mind, knowing the system besides providing values can act accordingly to a specific situation thus minimizing power consumption. Although it does not have a huge market here in Puerto Rico, it still helps in the process of improving our aquaculture farms and boosts the food production here in the island. The prototype has a legal aspect of providing safety encasing pertaining to electrical wires and their proximity to water. To avoid an accident all modules are safely placed inside impermeable boxes. Finally, the system has a low environmental impact even though it consists of electronic components and batteries if these are properly disposed by the user it should continue to minimize impact. The proper disposal of this equipment will be explicitly stated in the modules.

Future Work

The prototype requires some improvements with regards to software. Saving the values submitted by the user in the main system is desired in order to restore proper regulation if power was reestablished and offering the user a wider range of temperature and oxygen limit ranges.

Future upgrades for the AMS include running whole system using solar energy by adding solar cells. Also, adding more parameter readings like water conductivity to detect levels of diluted salts in the water, and PH to detect water acidity levels which can harm fish. While including more sensors or readings may seem great, even better will be to collect and study all this data. Finally to increase automation an automatic food dispensing mechanism, with the ability to intercommunicate with the AMS, can be included as a product.

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[16] Universal Solar Products Inc. http://www.universalsolar.com/

Appendix A – Glossary

1. **AMS -** Aquaculture Maintenance System
2. **MCU** - Microcontroller Unit
3. **UART -** Universal Asynchronous Receiver and Transmitter
4. **GPIO** - General Purpose Input and Output
5. **PWM** - Pulse Width Modulation
6. **WRL** – Wireless
7. **LCD** – Liquid Crystal Display
8. **LED** – Light Emitting Diode
9. **SPST** – Single Pole Single Throw
10. **CMOS** – Complementary Metal-Oxide Semiconductor
11. **RX** – Receive Port
12. **TX** – Transmit Port
13. **Q1 & Q2** – Yearly quarters 1 and 2
14. **UIBox** – User Interface Box

Appendix B – User Requirements

User Requirements:

- Minimize power consumption of the actual system by implementing a prototype that makes use of sensors to estimate, when is necessary, the use of air and water pumps.

- Develop a mechanism to regulate water temperature between the ranges of 24°C and 28°C to enhance fish crop reproduction and profitability.

- Keep track and regulate dissolved oxygen levels in the tank using a sensor and launching an alarm to notify user when the levels drop below the minimum limit of 2ppm.

- Design a User interface to notify the user when there are critical levels of temperature and oxygen and/or when there are power outages that can affect the functionality of the system.

- Provide a power back up mechanism to supply energy while there is a power outage in order to maintain most of the system functions.

Appendix C – System Specifications and Standards

System Specifications

Module	Operating Voltages	Current Consumption (Max)	Power (Max)	Battery Life
UI Box	6V	115mA (Active)	413mW	1153h
Power Supply	115-125 Vrms	760mA	45W	88% efficiency
Control System	12V and 3.3V	1.6A (Active)	26W	16h

Table C.0 – System Specifications

Heat Convection Calculations

A good estimate to calculate how much time it will take to heat the fish tank is defined as the weight of water in pounds (wlbs) over the BTU of the water heater multiplied by the hours it takes to heat 1 degree Fahrenheit (1Fhr) in water.

$$\frac{wlbs}{BTUs} * 1Fhr = time\ (hrs)$$

The BTUs of the water heater depends of how the day is. For instance if it is a clear sunny day the BTUs the solar panels will receive is 2,000 BTU/day. On a mildly cloudy day it will receive 1,388.89 BTU/day and on a cloudy day it will receive 777.78 BTU/day. The following table provides the time for each of the cases for a tank of 250 gallons and a solar water heater with $18ft^2$ panels.

Type of day	BTU/day	Hours to heat 3˚F
Clear	2,055	3.6
Mildly Cloudy	1,388.89	5.4
Cloudy	777.78	9.7

The most critical case is when the day is most cloudy because it will take approximately 9.7 hrs. to heat the water tank. On the plus side since the water tank will drain water at the same time the hot water is being poured in, this will most likely reduce the time of water heating. This is a good guideline to estimate how much time the water heater needs to be turned on.

Standards

X-Bee Standards

X-Bee is the brand name from Digi International for a family of form factor compatible radio modules. The X-Bee is based on the 802.15.4-2003 standard designed for point-to-point and star communications at over-the-air baud rates of 250 kb/s with a 1% packet error rate. The baud rate used for the X-Bee will be 9600 with parity bit of 0 and 1 control bit. Following is a Quote resuming the description of the 802.15.4-2003 standard:

IEEE Std 802.15.4-2003

This standard defines the protocol and interconnection of devices via radio communication in a personal area network (PAN). The standard uses carrier sense multiple access with a collision avoidance medium access mechanism and supports star as well as peer-to-peer topologies. The media access is contention based; however, using the optional super frame structure, time slots can be allocated by the PAN coordinator to devices with time critical data. Connectivity to higher performance networks is provided through a PAN coordinator.

This standard specifies two PHYs: an 868/915 MHz direct sequence spread spectrum (DSSS) PHY and a 2450 MHz DSSS PHY. The 2450 MHz PHY supports an over-the-air data rate of 250 kb/s, and the 868/915 MHz PHY supports over-the-air data rates of 20 kb/s and 40 kb/s. The PHY chosen depends on local regulations and user preference.

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated to this standard within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Details on the contents of this standard are provided on the following pages. [6]

Appendix D – Analysis of Alternatives

Decision Problem	Criteria	Alternative 1	Alternative 2	Test Case	Alternative Chosen
Voltage Regulator	Efficiency	Buck Converter (95%)	Linear Regulator (70%)	17V to 15V at 3A	Buck Converter
Voltage Regulator	Efficiency	Buck Converter (89%)	Linear Regulator (56%)	15V to 3.3V At 10mA	Buck Converter
Battery Charger Circuit	Current Control	Buck Converter (internal)	555 Charger (External)	15V to 12V At 1.5A	Buck Converter
MCU selection	Price Vs. Functionality	MSP430FR5739 (High Cost, Over-Func.)	MSP430G2452 (Low Cost, Enough Func.)	GPIO numbers and PWM available	MSP430G2452
User Interface	Overlapping Functionality	UI BOX (Simpler with more functions)	GSM (Redundant and limited functions)	Sensors Alarms and operating points	UI BOX
RF-Transmitter	Price Vs. Functionality	X-Bee (Low cost enough functions)	Bluetooth (High cost enough functions)	Data Transmitting for up to 100m	X-Bee

Table D.0 Hardware Analysis of Alternatives

For the User Interface Box, some microcontrollers were taken into consideration. They were the MSP430FR5739, Arduino Uno and Arduino Mega2560. The factors taken under consideration were that the device had to contain UART capabilities with at least one pair, low power consumption including low power mode to increase battery durability, met the 19 pins required to interface the system, and it does not require a high MCU frequency. **Table D.1** shows the comparison between them

	Number of Pins	Power	Low Power Mode	UART	Cost
Arduino Uno	14, Only two pins for interrupt	5v with ~40mA per pin	Yes, 4 modes	1	$27.47
Arduino Mega	54, 6 pins for interrupts	5v with ~40mA per pin	Yes, 4 modes	4	$53.57
Msp430Fr5739	40, with many ports with interrupt	3.3v with ~6mA per pin	Yes, 6 modes	2	$35.00

Table D.1 Software Analysis of Alternatives

The chosen microcontroller was the MSP430Fr57

Appendix E – Hardware Design Schematics and Component Calculations

User Interface Box

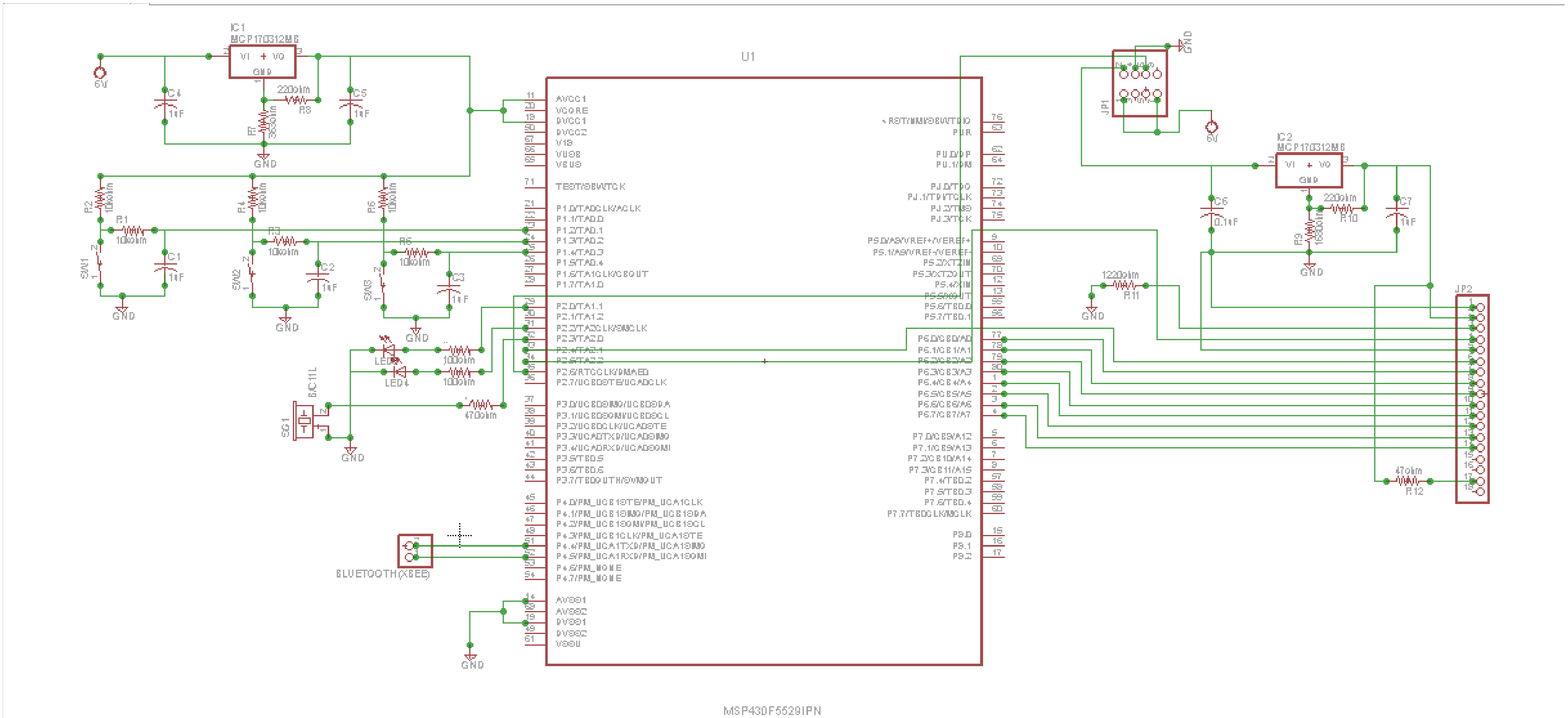


Figure E.0 *- The User Interface Box displays real-time oxygen and temperature data and lets the user control the parameter limits. A buzzer is activated when oxygen levels go below 1.5ppm, when the temperature goes two degrees below the minimum limit the user specified and/or if the power supply has low battery. A Green LED turns on when the system is taking proper action to regulate metrics and a Red LED when there is a system failure and the system was not allowed to take proper action.*

User Interface Box Components

Components	Part No.
Buzzer	COM-07950
LED	COM-00553 (RED) & COM-09650 (GREEN)
X-Bee	WRL-08665
T-Gate	TC74HC4066APF-ND
Switches (Button)	MB2411JW01-A-1A
LCD Display	LCD-00255
Resistors	10KΩ (2), 16KΩ (2), 200Ω, 1KΩ
Capacitors	1μF (2), 0.1μF, 100μF, 0.47μF, 0.33μF
MCU	MSP430FR5739
DC-DC Converters	LM3940 (3.3V), LM2931 (4.5-5V)
Box	Dimensions 6x4x2"

Table E.0 – User Interface Panel Components

Calculations

Capacitors
Capacitors for the DC Converters were chosen according to the datasheets, these were the minimum capacitances required to maintain stability. These values may be increased. Larger values of output capacitance will give improved transient response.

Resistors

$$Rbuzzer = \frac{(3-0)V}{.006A} = 500\Omega$$

The resistance was duplicated to 1K Ω to avoid using the maximum current.

$$Rled = \frac{(3-2-0)V}{.006A} = \sim 200\Omega$$

Data
$C_1 = 1\mu F$ $t_{bounce} = 20ms$ $V_T = 1.6V$

$$Rswitches = \frac{t_{bounce}}{C_1(\frac{Vdd}{Vdd - V_T})} = 26k\Omega$$

$$R_{min} = R_1 + R_2$$
$$R_{min} - R_2 \leq R_1$$
$$R_1 = 10K\Omega \qquad R_2 = 16K\Omega$$

It was noticed that 16KΩ was not enough to comply to the 20ms because, $16K\Omega * 1\mu F = 16ms$ instead, we decided to use R_2=32KΩ.

Power Consumption

Component	Quantity	Total Current (mA)	Operating Voltage (V)	Power (mW)
LEDs	2	40	3.3	132
Push Buttons	3	0.99	3.3	3.267
LCD	1	20	5	100
Buzzers	1	3.3	3.3	10.89
MCU	1	0.4	3.3	1.32
X-Bee	1	50	3.3	165
Total		115	P_{act}	412.477

Table E.1 - Active Mode UI Box Power Consumption

Component	Quantity	Total Current (mA)	Operating Voltage (V)	Power (mW)
LEDs	2	0	3.3	0
Push Buttons	3	0	3.3	0
LCD	1	0	5	0
Buzzers	1	0	3.3	0
MCU	1	0.175	3.3	0.5775
X-Bee	1	0.01	3.3	0.033
Total		0.0185	P_{lp}	0.6105

Table E.2 - Sleep Mode UI Box Power Consumption

Battery Life

Component	Formula	Equation	Value
Average Power Consumption	$0.03*P_{act} + 0.97*P_{lp}$	0.03*413m + 0.97*0.613m	13mW
Battery Life	$(B_{cap}*V_{batt})/APC$	(2500mAh*6V)/13mW	1153h

Table E.3 - Battery Life Calculations

Control System Schematic

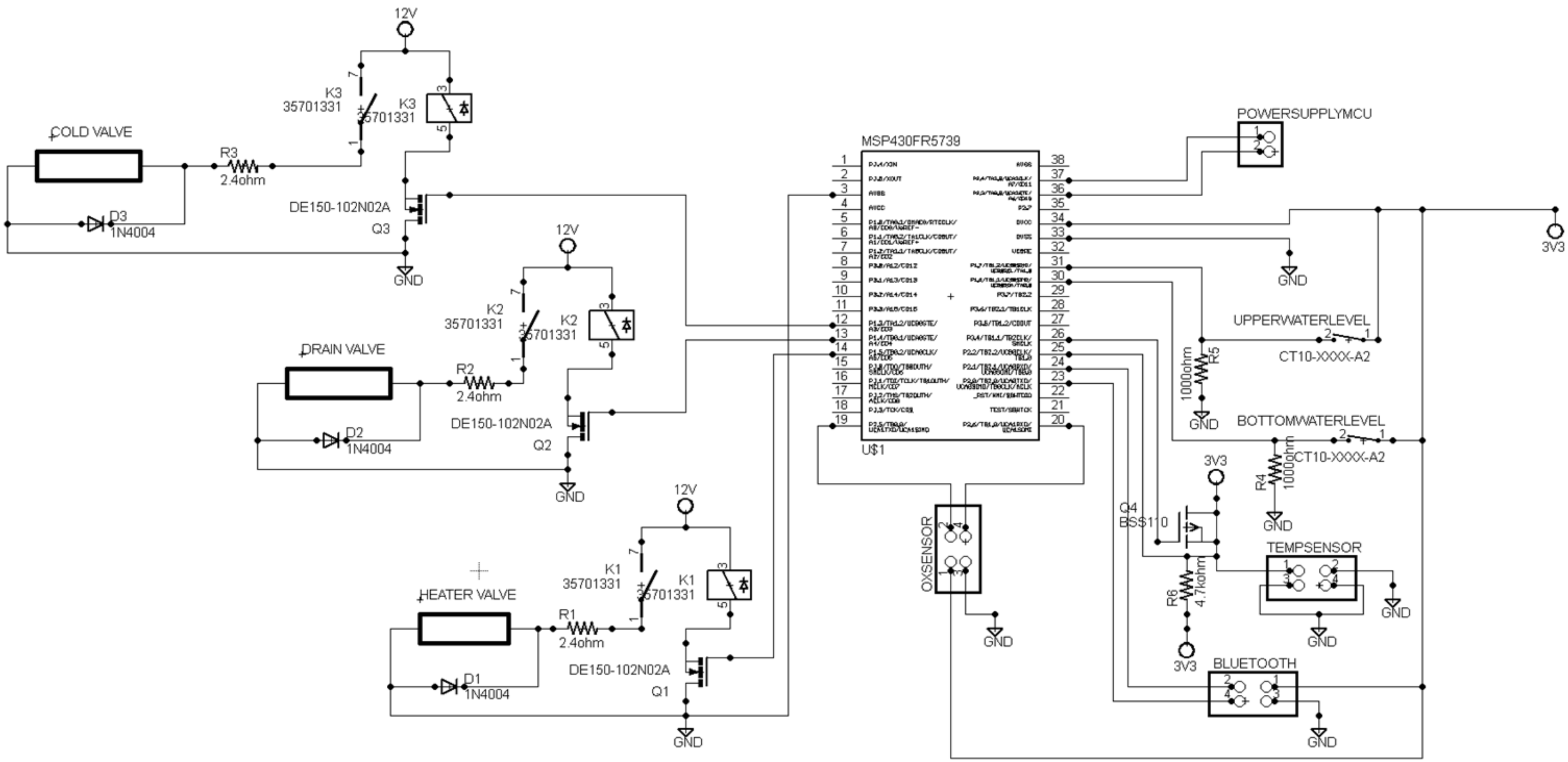


Figure E.1 *- The control system is in charge of receiving input information of each one of the sensors (temperature, oxygen and water level indicators) and with the given information it should open or close the three valves accordingly, in order for the system to take appropriate action to correct the quality control metric.*

Control System Components

Components	Part No.
Relay	G5T-1A DC12
Diode	1N5822
MCU	MSP430FR5739
Resistors	1KΩ (2), 4.7kΩ, 2.4Ω (3)
Temperature Sensor	DS18B20
X-Bee	WRL-08665
Oxygen Sensor	Dissolved Oxygen Circuit, Atlas Scientific
Water Level Indicators	Amico Tanks Horizontal Liquid Float Switch Water Level Sensor (B/W)
Transistor (Power MOS – 12V)	CSD18504KCS

Table E.4 – Control System Components

Control System Calculations

Resistors

$$R_{relay/valve} = \frac{12V}{5A} = 2.4\Omega$$

$$R_{waterlevel} = \frac{3.3V}{.006A} = 1K\Omega$$

According to datasheet:

$$R_{TempSensor} = 4.7K\Omega$$

Power Consumption

Component	Quantity	Total Current (mA)	Operating Voltage (V)	Power (mW)
Valves	3	1200	12	14400
Relays	5	175	12	2100
Water Level Sensor	1	3.3	3.3	10.89
Temperature Sensor	1	5.5	3.3	18.15
Oxygen Sensor	1	20	3.3	66
MCU	2	0.8	3.3	2.64
Air Pump	1	150	120Vrms	9000
X-Bee	1	50	3.3	165
Total		1604.6	P_{act}	25762.68

Table E.5 - Active Mode Control System Consumption

Component	Quantity	Total Current (mA)	Operating Voltage (V)	Power (mW)
Valves	3	0	12	0
Relays	5	0	12	0
Water Level Sensor	1	0	3.3	0
Temperature Sensor	1	1	3.3	3.3
Oxygen Sensor	1	4	3.3	13.2
MCU	2	0.35	3.3	1.155
Air Pump	1	0	120Vrms	0
X-Bee	1	0.01	3.3	0.033
Total		5.36	P_{lp}	17.688

Table E.6 - Sleep Mode Control System Consumption

Battery Life

Component	Formula	Equation	Value
Average Power Consumption (APC)	$0.2*P_{act} + 0.8*P_{lp}$	0.2*25763m + 0.2*18m	5168mW
Battery Life	$(B_{cap}*V_{batt})/APC$	(7200mAh*12V)/5168mW	16h

Table E.7 - Control System Battery life Calculations

Power Supply Schematic

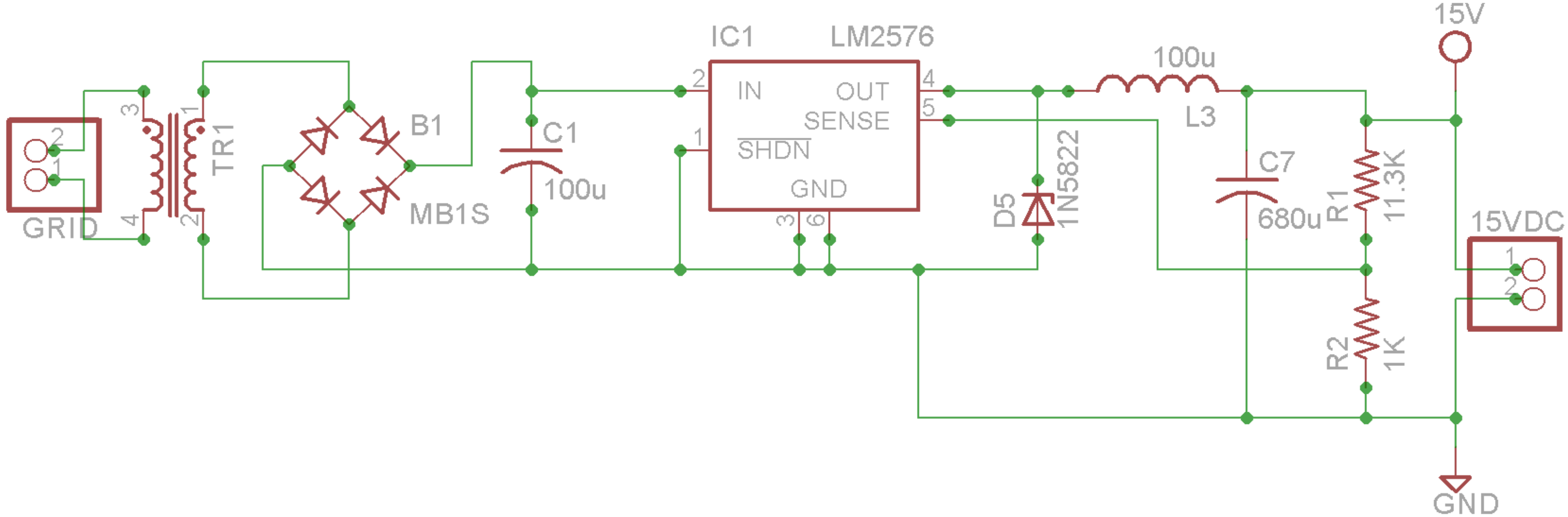


Figure E.2 - *The power supply will be in charge of supplying the necessary power for the entire system. The input to the power supply is the electric utility or grid, afterwards a transformer is used to step down the high voltage (120Vrms), to 12Vrms which is then rectified by a diode bridge and filtered by a capacitor. The resulting dc voltage is about 17V which is supplied to a Buck Converter in order to reduce it to the desired 15V, the LM2576 IC is used for the switching part of the Buck and the two resistors at the output are meant for feedback purposes.*

Power Supply Components

Components	Part No.
Diode Bridge	GBU4A
Capacitor	100uF (1), 680uF (1)
Buck Module	LM2576
Resistors	11KΩ (1), 1kΩ (1)
Diode	1N5822
Inductor	100uH
Transformer	14A-56-36B42

Table E.2 Power Supply Components

Power Supply Calculations

Inductor:
For fixed output voltages the manufacturer provides a table for the selection of the specific inductor according to the maximum load current and the maximum input voltage for a specific output voltage, in this case the inductor has to be greater than 68uH. A value of 100uH was selected instead.

Input Capacitor:
Manufacturer recommended the use of a 100uF capacitor for bypass at the input of the Buck.

Output Capacitor:
For fixed output voltages the manufacturer provides a table for the selection of the specific capacitor according to the specific output voltage, in our case the capacitor has to be greater than 470uF so a value of 680uF was selected instead.

Transformer:
The transformer have to be able to handle 3A max at the output and step down the voltage from 120Vrms to 12Vrms, so the transformer turn ratio is 10:1.

Resistances:
R2=1Kohm was selected in order to calculate R1, Vref is a value from the internal circuit of the buck module:

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

$$R_2 = 1K * \left(\frac{15V}{1.23V} - 1\right) = 11.3K$$

Battery Charger Schematic

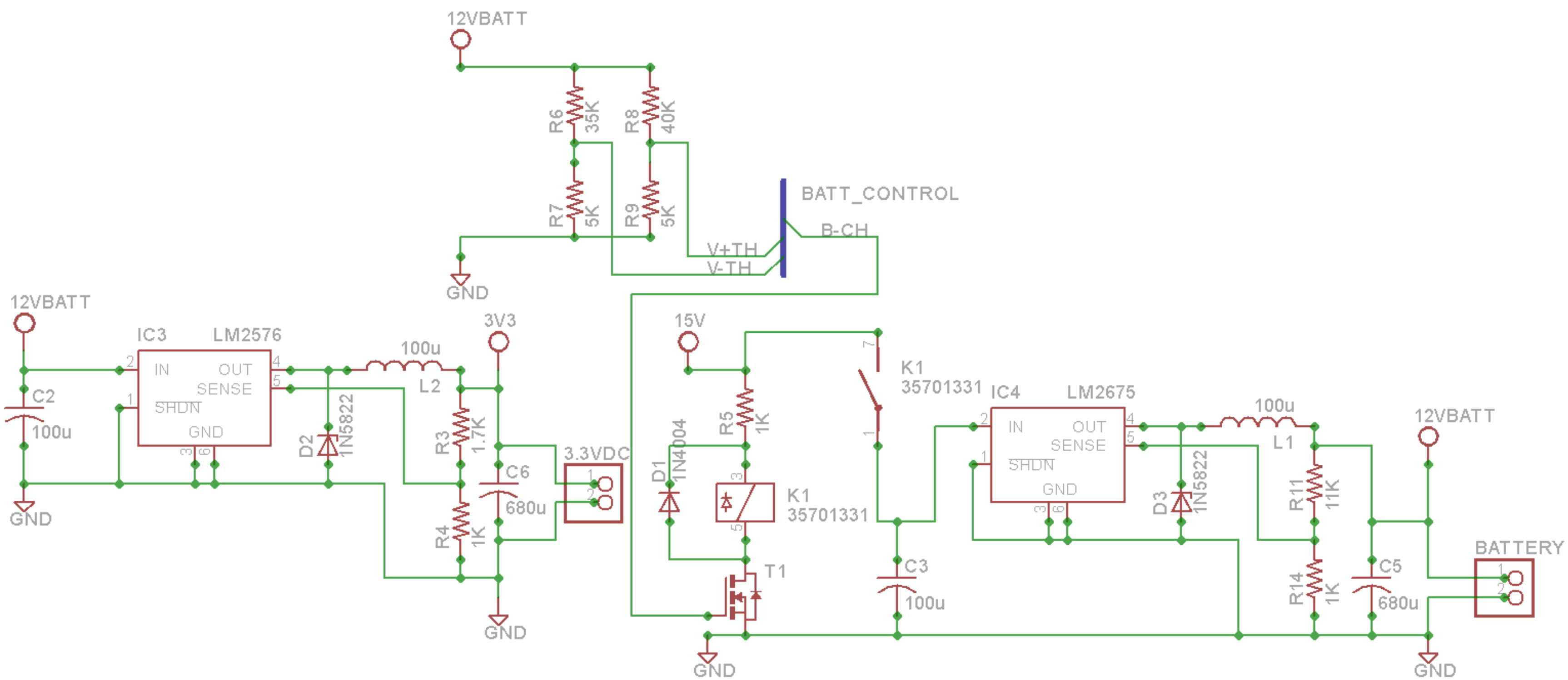


Figure E.3 *- The battery charger has another Buck converter to step down the 15Vdc to 3.3Vdc, which is going to be used to supply the MCU needed for the power supply module. Afterwards, we have all the circuitry to charge the battery: two voltage dividers formed by resistances R6 to R9 to sense the voltage level at the battery and are used to determine when the battery requires to be charged. A relay is used to turn on the Buck converter that controls the current flowing into the battery when it is charging, which also has an internal mechanism to sense and limit the current out to the battery. Finally, the relay is turned on using a power MOSFET and the signal from one of the GPIOs of the MCU.*

Battery Charger Components

Components	Part No.
Relay	G5T-1A DC12
Capacitor	100uF (2), 680uF (2)
Buck Module	LM2576, LM2675
Resistors	11KΩ (1), 1kΩ (3), 1.8kΩ (1), 5kΩ (2), 35kΩ (1) and 40kΩ (1),
Diode	1N5822 (2), 1N4004(1)
Inductor	100uH(2)
Power MOSFET	CSD18504KCS

Table E.2 – Battery Charger Components

Power Supply Calculations

Inductor:
For fixed output voltages the manufacturer provides a table for the selection of the specific inductor according to the maximum load current and the maximum input voltage for a specific output voltage, in our case the inductor has to be greater than 68uH so we selected a value of 100uH.

Input Capacitor:
Manufacturer recommends the use of a 100uF capacitor for bypass at the input of the Buck.

Output Capacitor:
For fixed output voltages the manufacturer provides a table for the selection of the specific capacitor according to the specific output voltage, in our case the capacitor has to be greater than 470uF so we selected a value of 680uF.

Resistances:

1. R4=1KΩ was selected in order to calculate R3, the same for R11 and R14. V_{ref} is a value from the internal circuit of the buck module:

$$R_2 = R_1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

$$R_2 = 1K * \left(\frac{3.3V}{1.23V} - 1\right) = 1.7K \approx 1.8K$$

2. R5 for the Relay was selected to provide a current for 15mA in order for the relay to be activated.

$$R_5 = \frac{15V}{15mA} = 1K$$

3. R6 and R8 where selected to provide to the MCU with a voltage of 1.5V when the battery is at 12V and at 13.5V, R7 and R9 where selected to be 5K to finally calculate R6 and R8:

$$1.5V = 12V * \frac{5K}{5K + R_6} \rightarrow R_6 = 35K$$

MCU Schematic

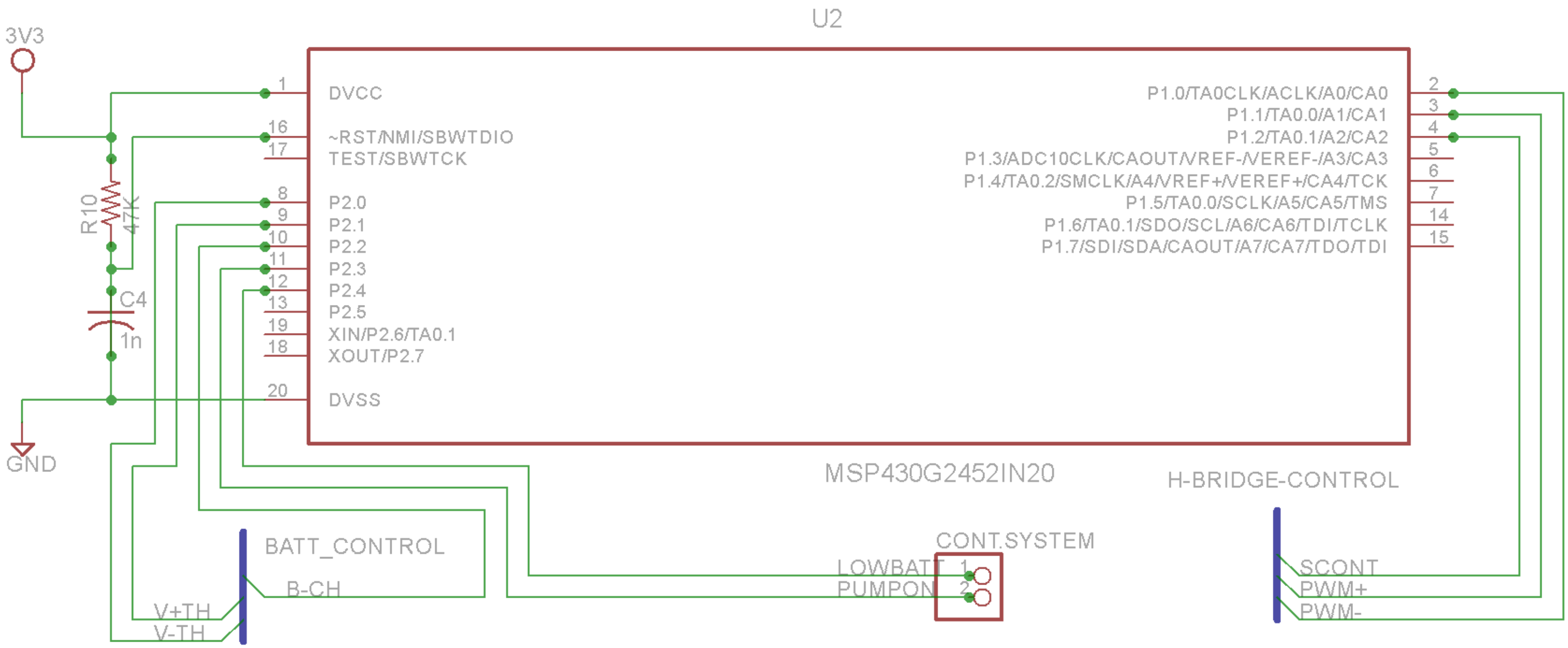


Figure E.4 *– In the MCU circuit P2.0 and P2.1 are used to sense the battery voltage to determine whether it is charged or it needs to be, P2.2 is used to turn on the relay to start charging, P2.3 and 2.4 are used to communicate with the control system. Three port pins (1.0-1.2) are used to control the air pump circuit. Port 1.0 decides if the air pump is going to be sourced by the utility or the battery, Port 1.1 and 1.2 provide the PWM signals for the inverter used to source the air pump with the battery.*

Inverter Schematic

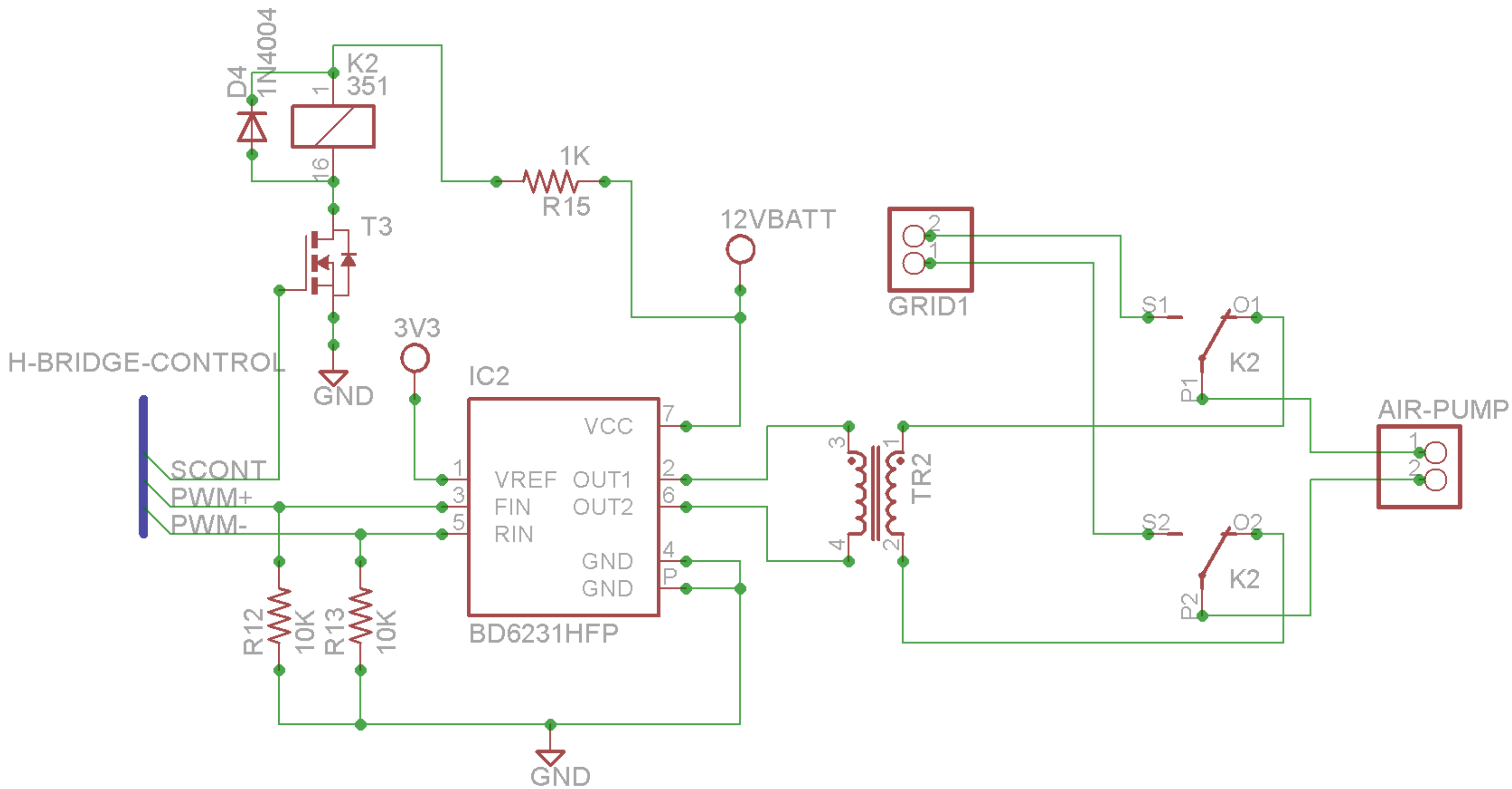


***Figure E.5** - The Inverter is composed of an IC BD6231HFP which is an H-Bridge. The signals from the MCU source the PWM to the inputs of the IC, the power supply used for the bridge is 12V directly from the battery. The output is connected directly to a transformer in order to step up the voltage to 120Vrms. Finally, a relay is turned on using a power MOSFET and a signal from the MCU to control the power source used to supply the air pump.*

Inverter Components

Components	Part No.
Relay	V23105A5403A201
Transformer	14A-56-36B42
H-Bridge	BD6231
Resistors	10KΩ (1), 1kΩ (1)
Diode	1N4004(1)
Power MOSFET	CSD18504KCS

Table E.3 – Inverter Components

Power Supply Calculations

Resistances:

1. R15 for the Relay was selected to provide a current of 35mA to activate it.

$$R_5 = \frac{12V}{35mA} = 350\Omega$$

2. R12 and R13 where selected according to the manufacturer's specification in order to speed up the turn off time of the transistors used on the H-Bridge, the selected value was 10K.

Transformer:

The transformer has to be able to handle a maximum current of 1A at the output and step up the voltage from 12Vrms to 120Vrms, so the transformer turn ratio is 10:1.

Appendix F – Hardware System Flowcharts

Oxygen Sensor Flowchart

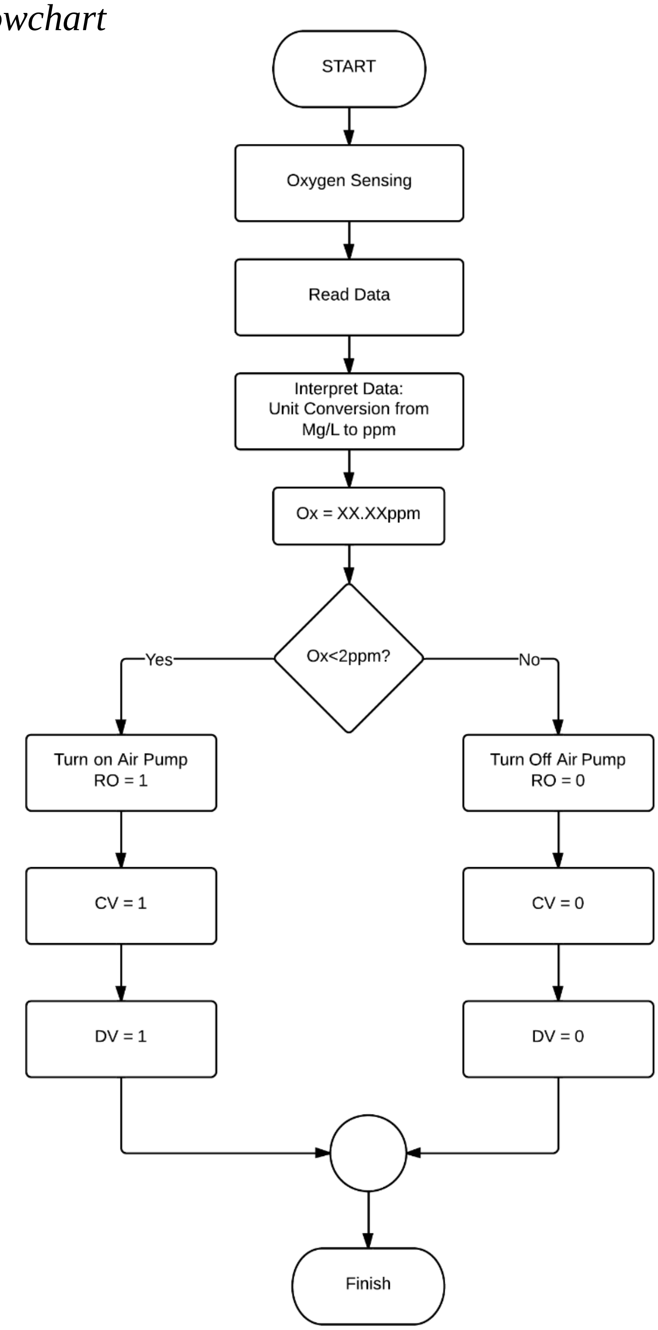


Figure F.0 – This flowchart illustrates the oxygen sensor operation. First of all, it will sense oxygen levels, read the data and convert its units from mg/L to ppm, to finally send it to the MCU. Once the MCU receives the reading it will determine if oxygen levels need to be regulated by turning the air pump on or off and the respective drain and tap water valves.

Temperature Sensor Flowchart

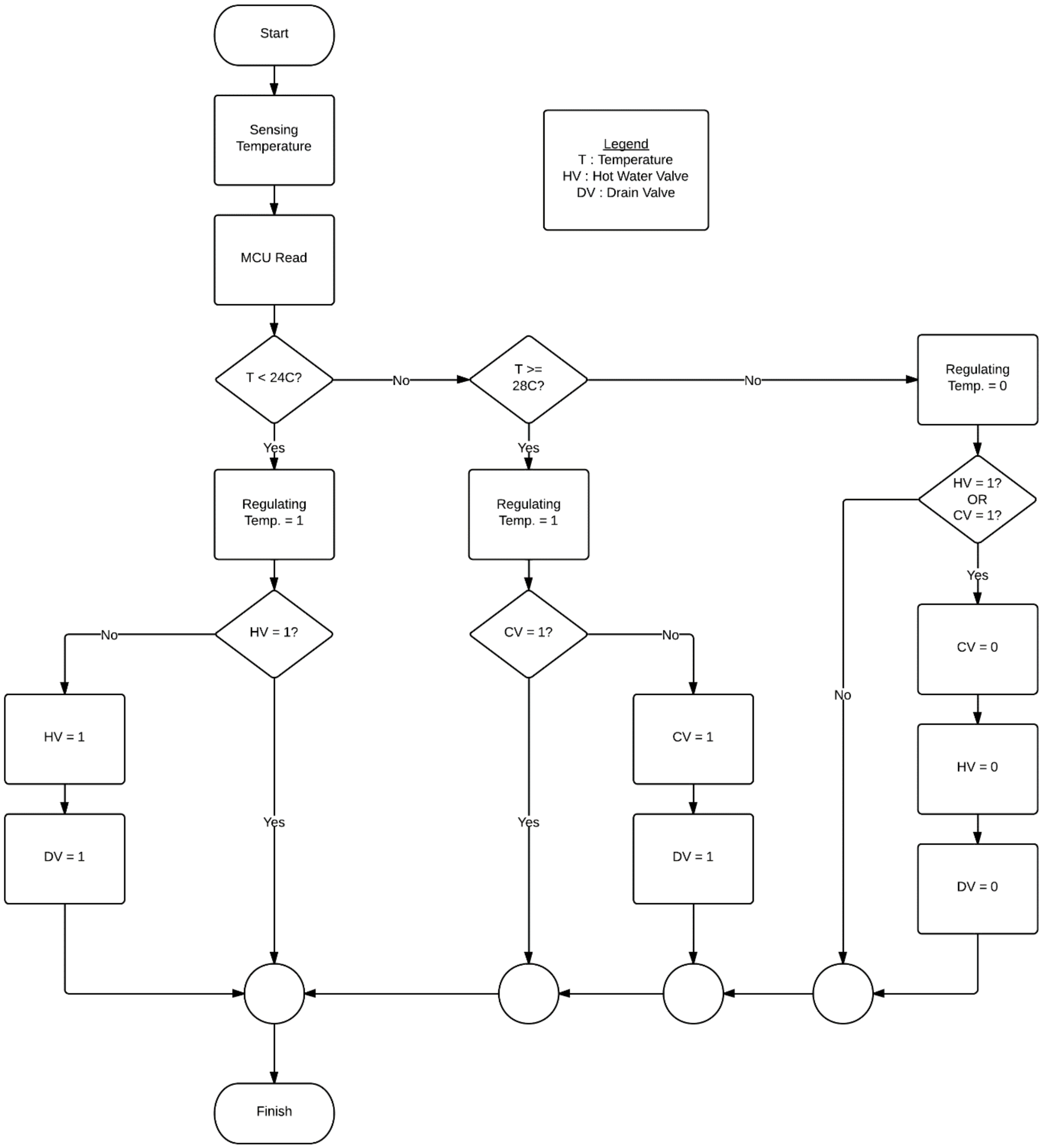


Figure F.1 - This flowchart illustrates the temperature sensing routine. It starts off by sensing temperature and sending the measurement to the MCU. If the temperature is lower than or higher than the user specified values (in this case 24˚C and 28˚C) then it will enter the water heating routine or the water chill routine. Else if these conditions are not met then the routine finishes and no action is taken in turn

Appendix G – System Architecture and Interfaces

Flowcharts

User Interface

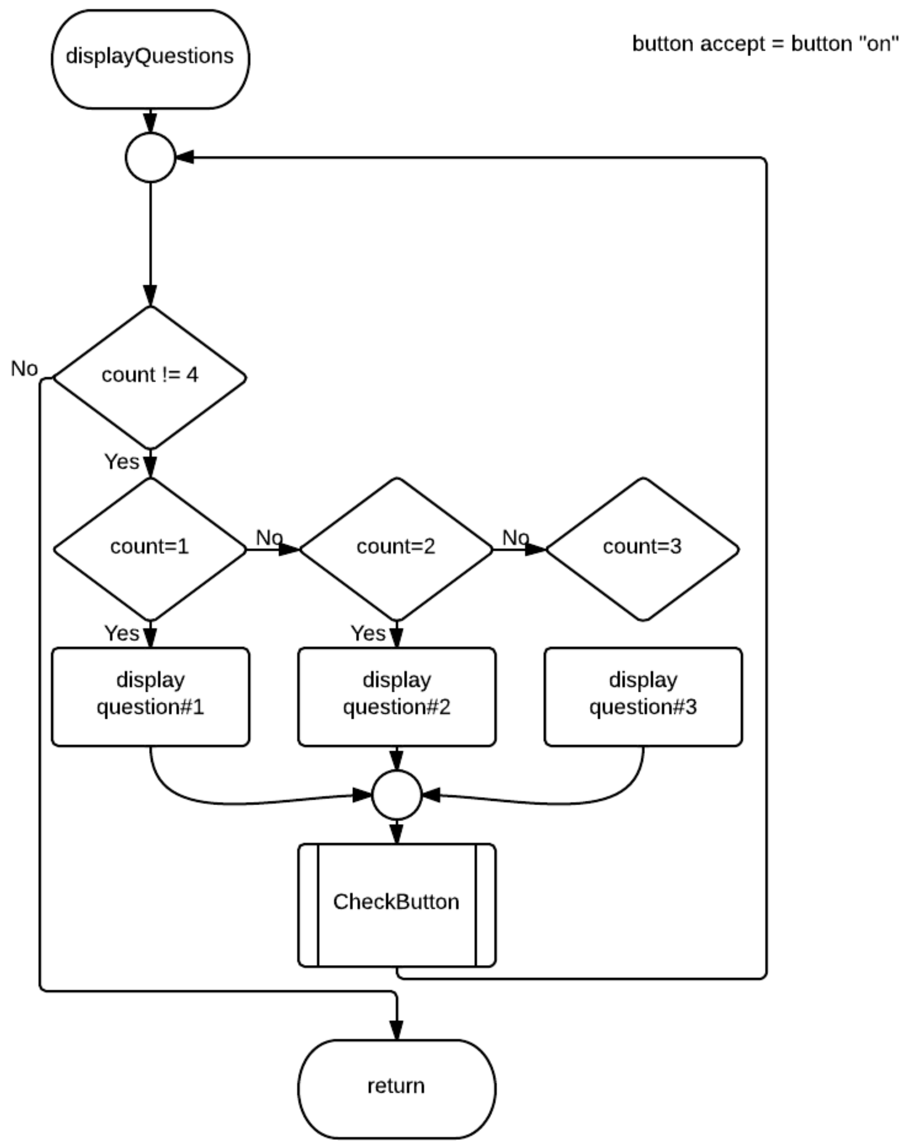


Figure G.0

Basically is a while loop waiting for acceptance from the user calling the method "check Button", to enable next question. Once all questions are answered it returns.

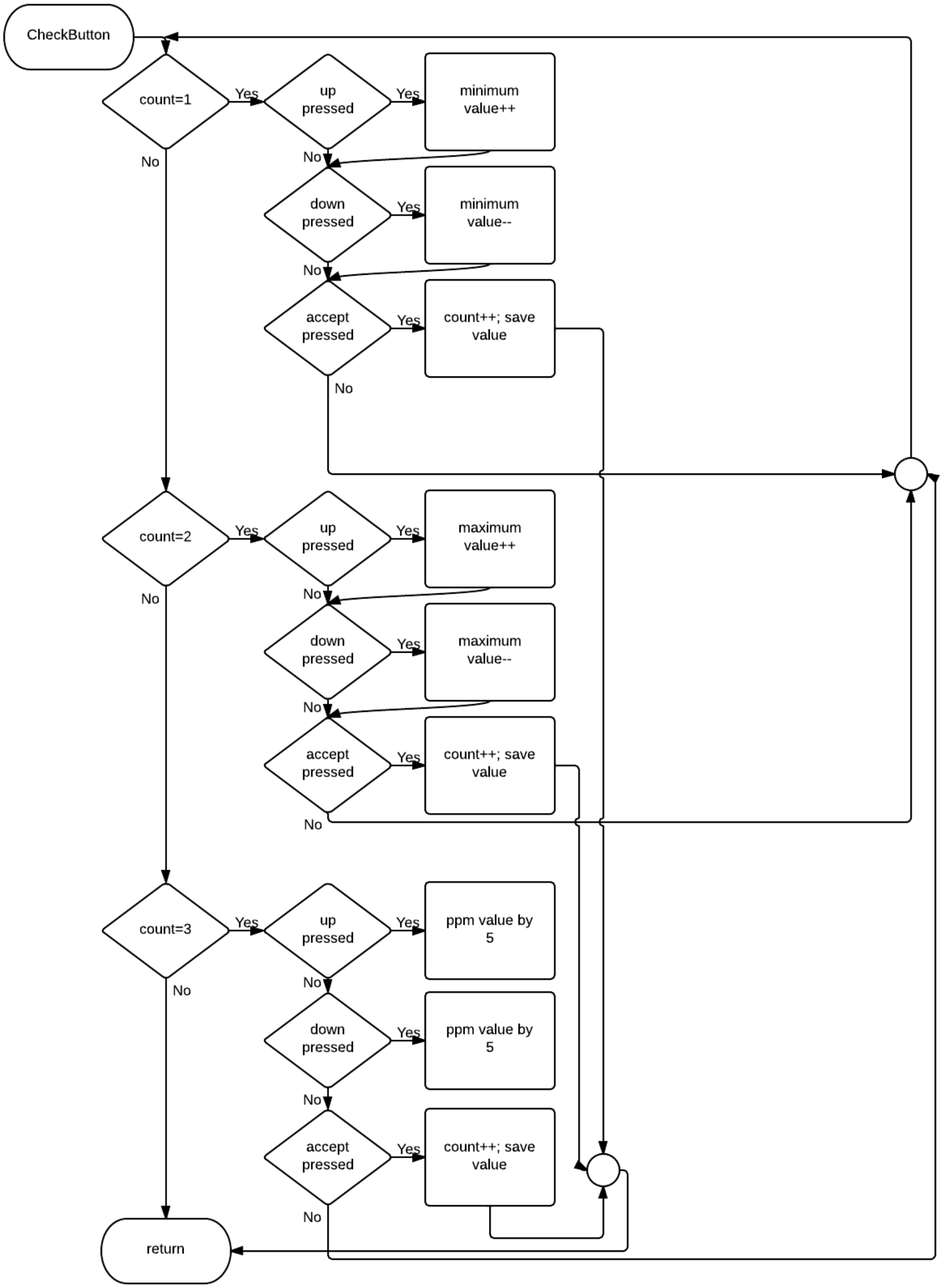


Figure G.1

This is the method called in the previous figure. Depending on the count is found three different options are provided. Move upward, downward in the values and accept the value in the screen. This allows user interaction with the sensor settings.

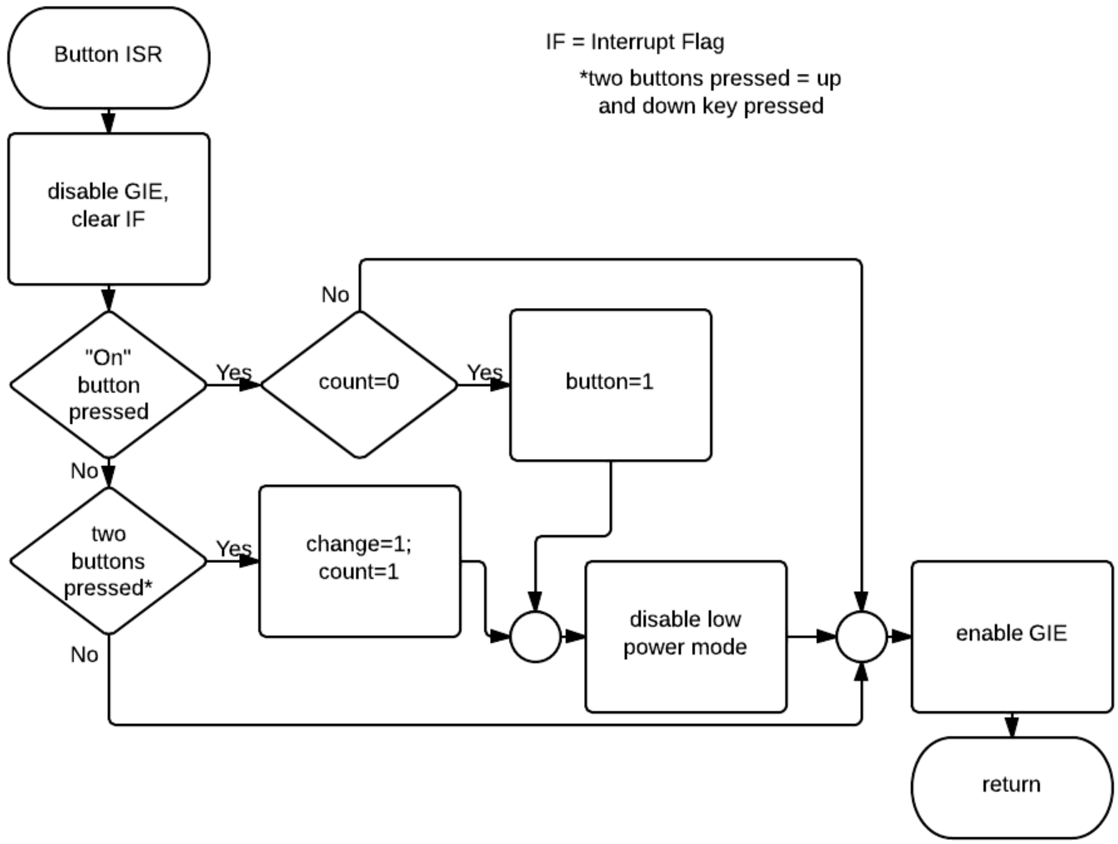


Figure G.2

This flowchart represents the option for interrupts. The “on button” is for turning the LCD on, and the “two buttons pressed” is for allowing system settings modification.

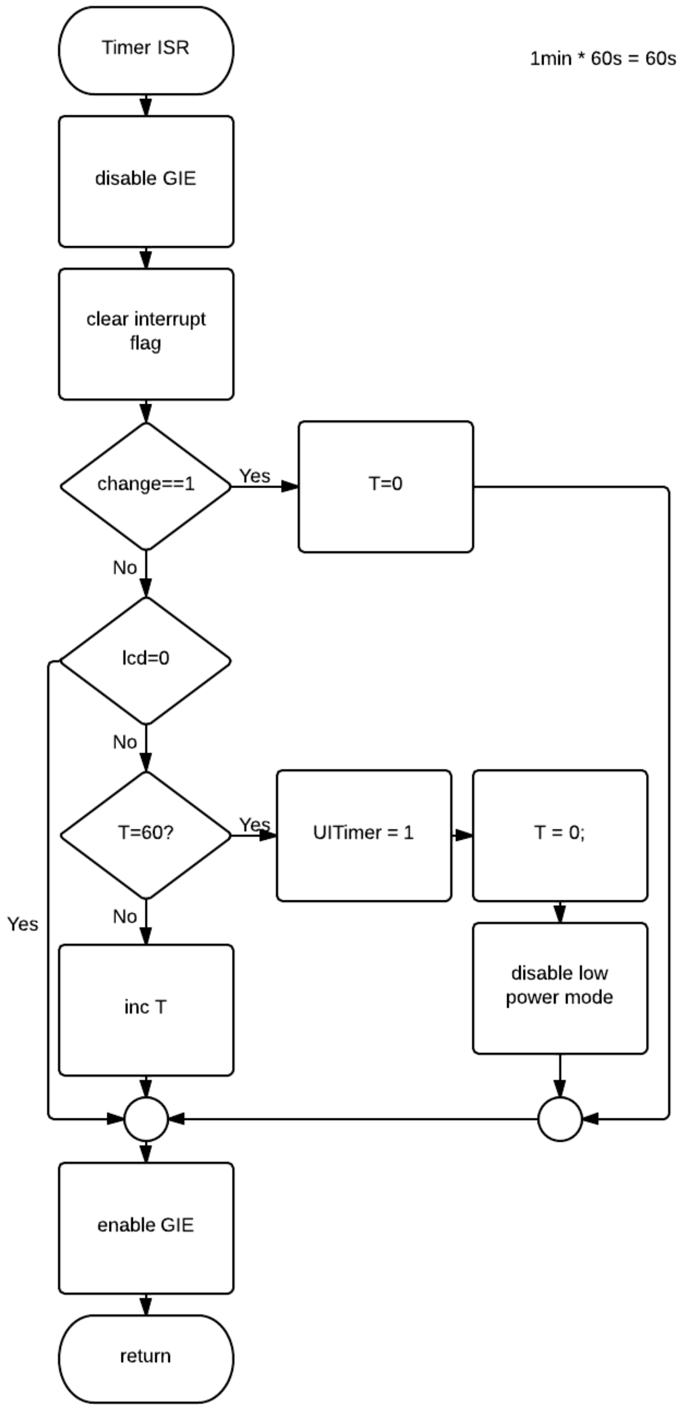


Figure G.3

This represents the timer for the screen. After one minute the LCD screen will turn off but if the user is in the middle of changing settings the counter will be on hold and reset.

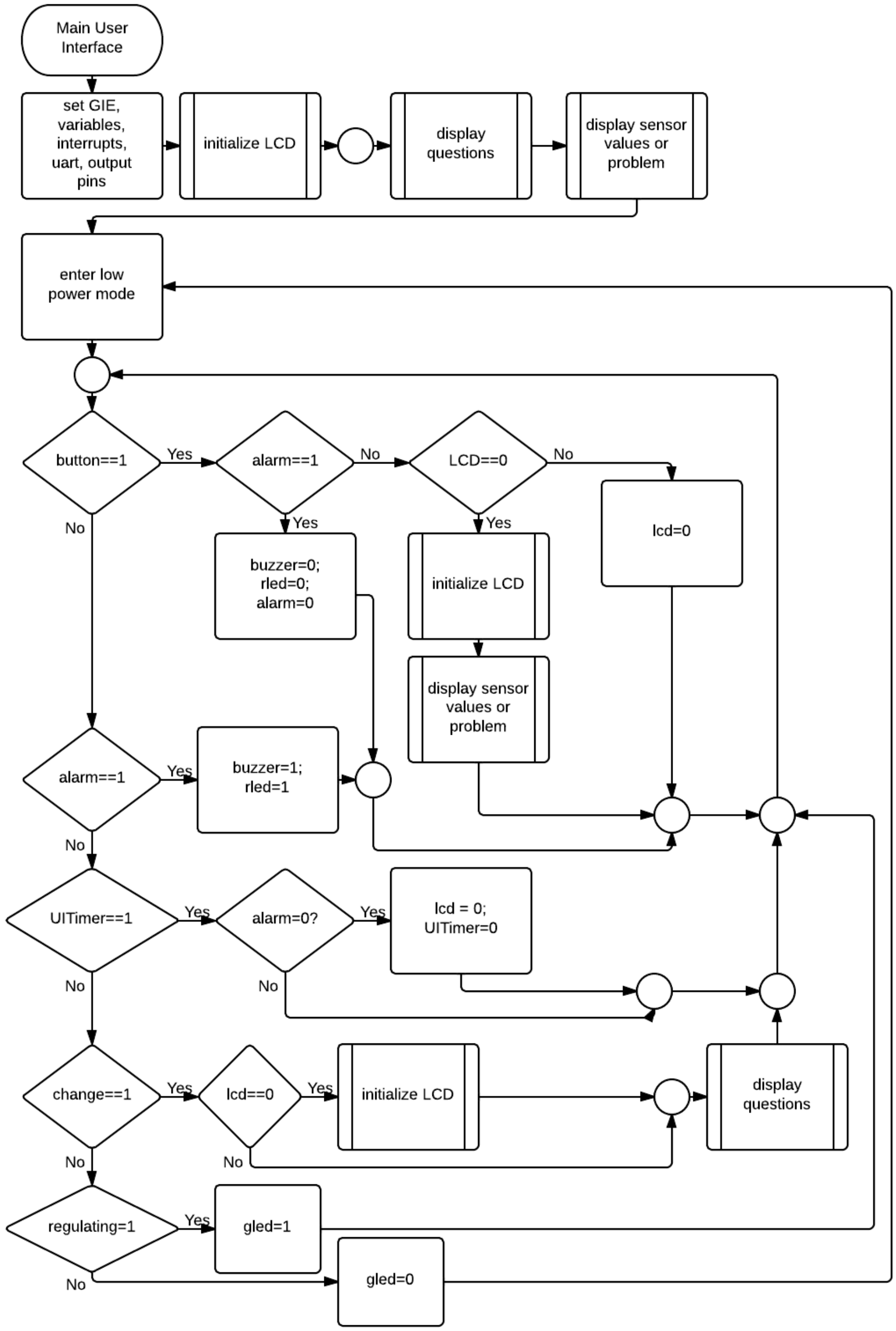


Figure G.4

This is the main program controlling the user interface. It will contain methods that will disable the low power mode and later check what flag is activated based on it and execute. Many different scenarios are found and that is the reason for many "if" question been realized.

Control System:

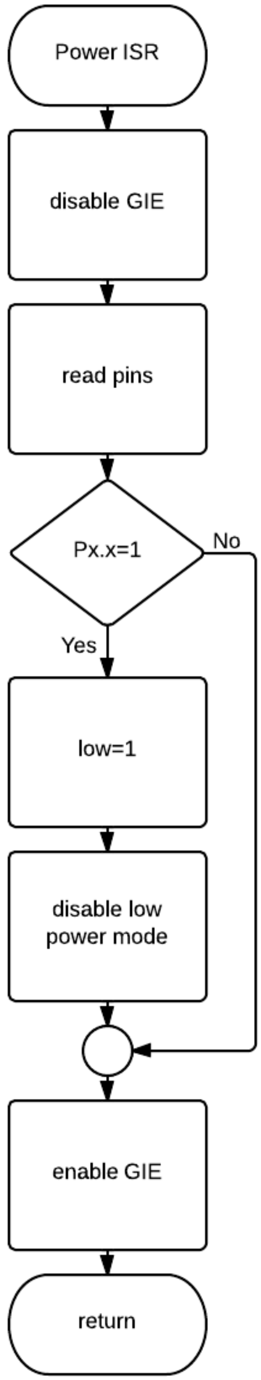


Figure G.5

This flowchart works like an interrupt when a high signal is sent from the MSP430G5529LP it indicates that the battery has reach low battery status, it sets a flag and disables low power mode.

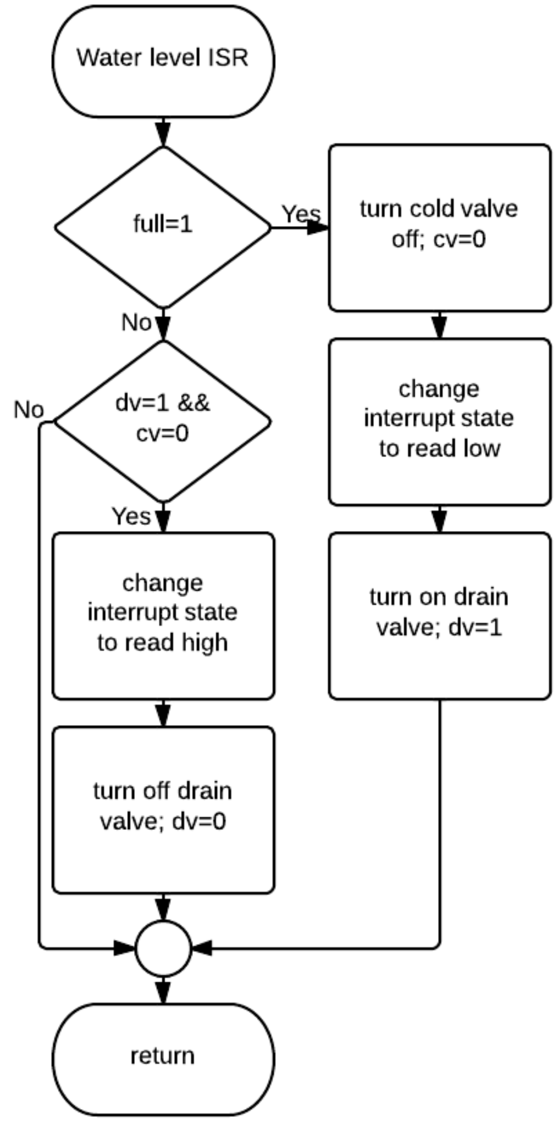


Figure G.6

This flowchart works like the first one; it uses interrupts to read the level where water has reached. When the upper sensor is sending a high value it opens the drain valve and waits for the sensor to read a low. Once a low voltage is detected, the drain closes and water is kept.

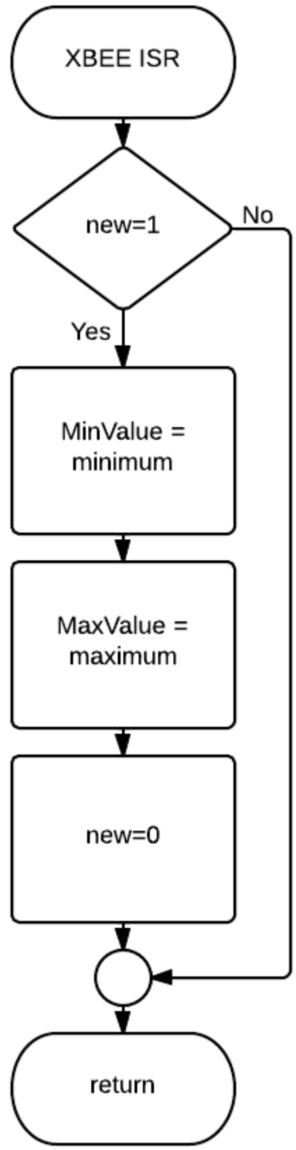


Figure G.7

This flowchart shows when new values are received and saved by the XBEE module in the System Control. These values will be used as comparison with the sensor readings.

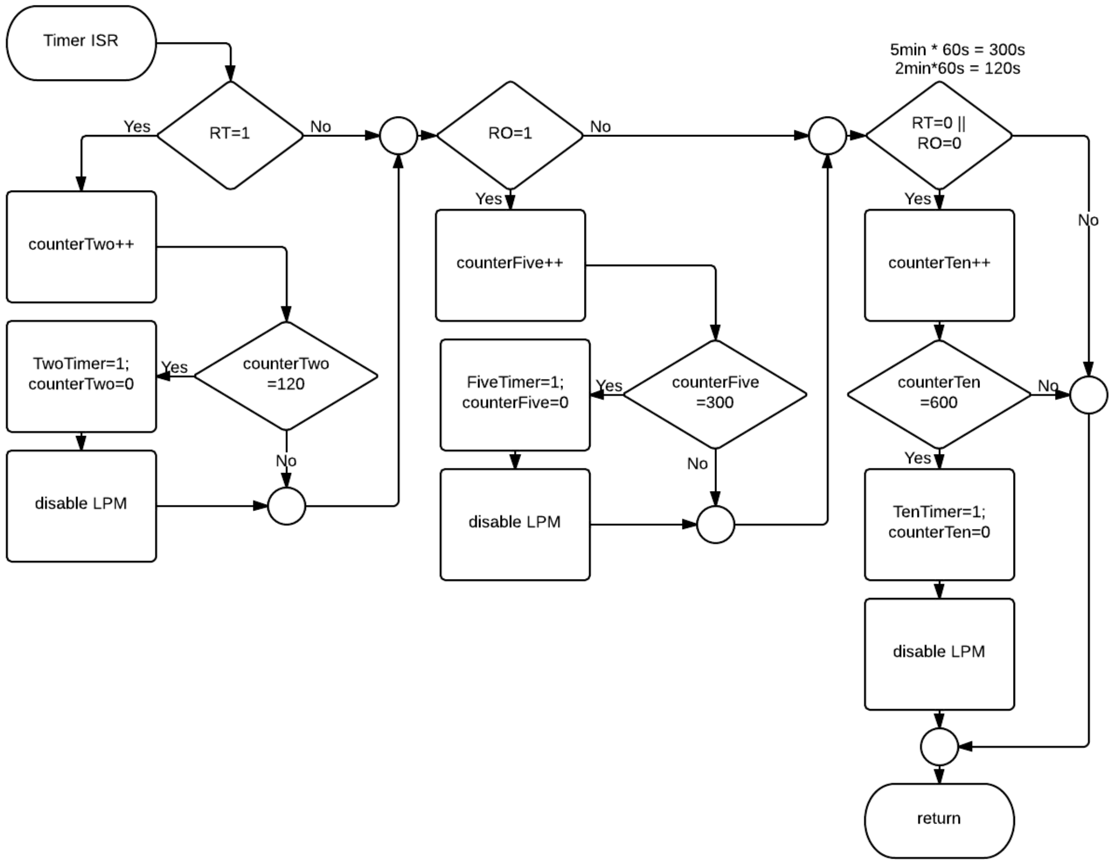


Figure G.8

This represents all timers used for water sensing. When the two, five, and ten minute timer activates it sets flags for the main program to execute once low power mode is disabled. While the two or five minute timer is counting the ten minute counter is in hold. Once these timers are done working the ten minute timer restarts its count.

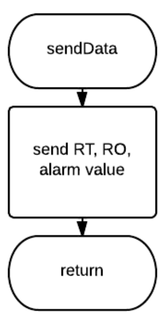


Figure G.9

This represents the method of sending data, using the X-Bee module, to the UIBox.

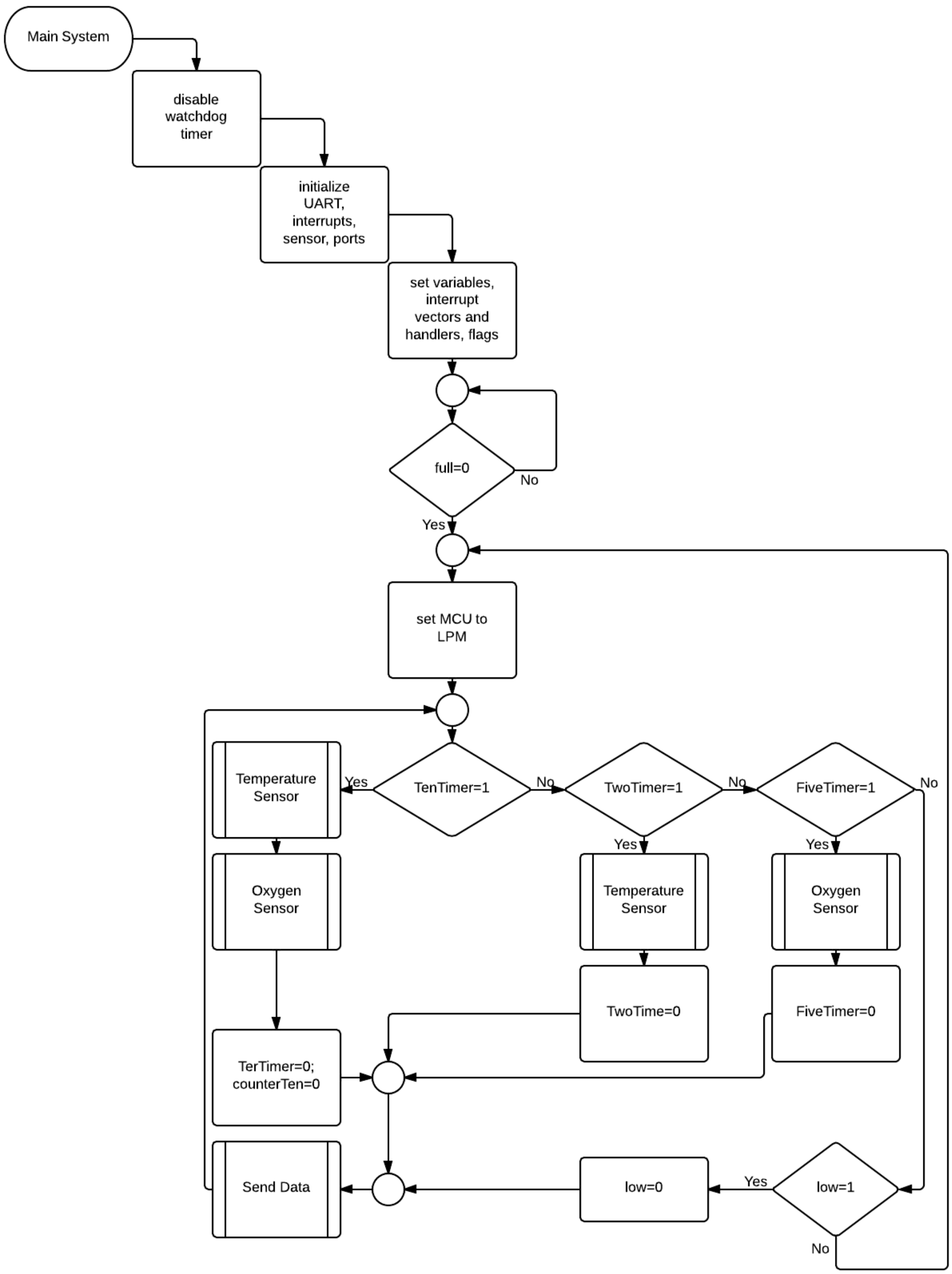


Figure G.10

Represents the main program in which all methods will be called. The code is set to firstly fill the tank and set the system in low power mode. The timer, XBEE communication, and signal interrupt may remove the MCU from low power mode. The flags will be read and depending on the ones set it will take the desired action. When the two and five timer is reached a reading to the temperature and oxygen sensor will be read, respectively. When the sensors are read, the system will send data.

Appendix H – Use cases, Mockups and Sequence Diagrams

Use Cases Diagram

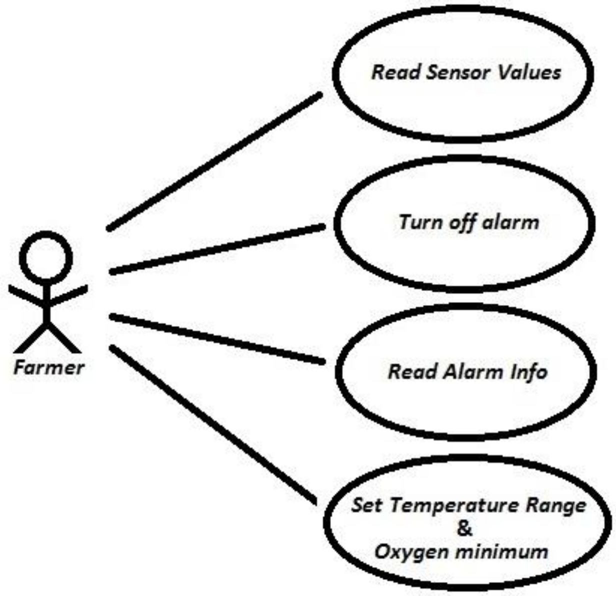


Figure - H.0

This diagram indicates what actions the user can take using the system, what is the goal the user can obtain. He can read the oxygen and temperature values detected in the tank. He can set the temperature range as well as the minimum oxygen (ppm) for the system to work with. Deactivate the alarm and is able to see what provoked it.

Use Cases Description

1. Name: Read Sensor Values
   Actor: Farmer
   Entry Condition:
   - Farmer in front of User Interface Box

   Exit Condition:
   - Farmer view values for Oxygen and Temperature Sensor

   Event Flow:
   - Farmer selects the option to turn display screen on.
   - Screen displays the name and value for each sensor, respectively.
   - Farmers read values.

2. Name: Turn off Alarm
   Actor: Farmer
   Entry Condition:
   - Farmer in front of User Interface Box
   - Alarm went off

   Exit Condition:

- Farmer disables alarm.

Event Flow:

- Farmer selects the option to turn off the alarm.
- Buzzer shuts down as well as led.
- Farmer has disabled the alarm.

3. Name: Read Alarm Info
Actor: Farmer
Entry Condition:
    - Farmer in front of User Interface Box
    - Alarm was active and the problem persists.

    Exit Condition:
    - Farmer views, in the display, what is causing a problem to the system.

    Event Flow:
    - Farmer selects the option to turn display screen on.
    - Screen displays what is causing the alarm.
    - Farmer reads the message.

4. Name: Set Temperature Range
Actor: Farmer
Entry Condition:
    - Farmer in front of User Interface Box.
    - First time box configuration.
    - Desires temperature range modification.

    Exit Condition:
    - Farmer sets minimal and maximum temperatures.

    Event Flow:
    -If first time box configuration;
    - Screen displays the first question.
    - Farmer enters value chosen.
    - Screen displays the second question.
    - Farmer enters value chosen.
    - System updates maximum and minimums.

    -else
    - Farmer selects the option to allow temperature modification.
    - Screen displays the first question.
    - Farmer enters value chosen.
    - Screen displays the second question.
    - Farmer enters value chosen.
    - System updates maximum and minimums.

Mock-Ups

Figure H.1 - It shows the startup screen for the system, the Logo

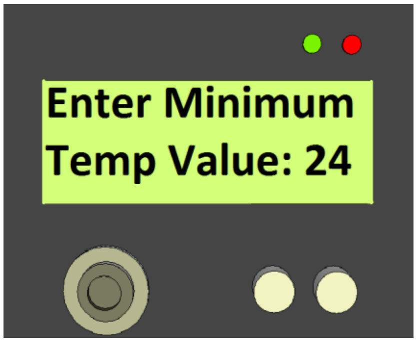


Figure H.2 - Ask user to enter minimum temperature desired.

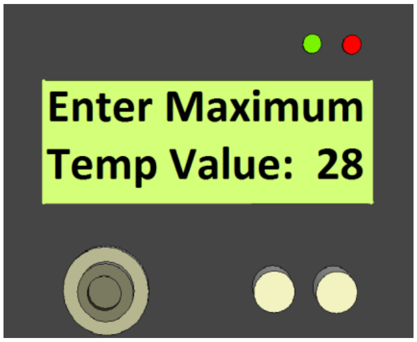


Figure H.3 - Ask user to enter maximum temperature desired.

Figure H.4 - Ask user to enter minimum ppm for oxygen level desired.

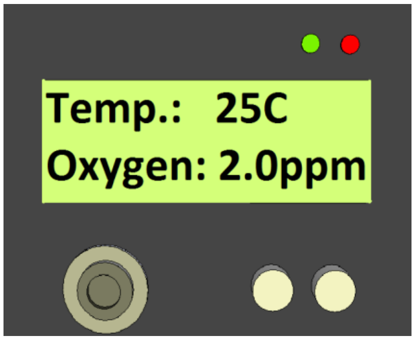


Figure H.5 - Information from the sensors in the water tank.

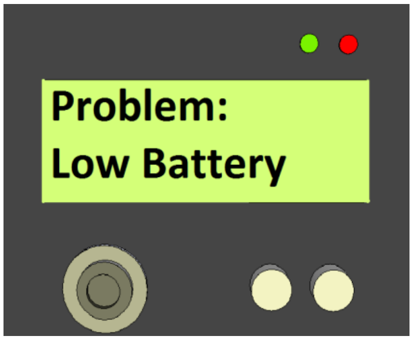


Fig.H.6 - Shows the problem that caused the alarm.

Sequential Diagram

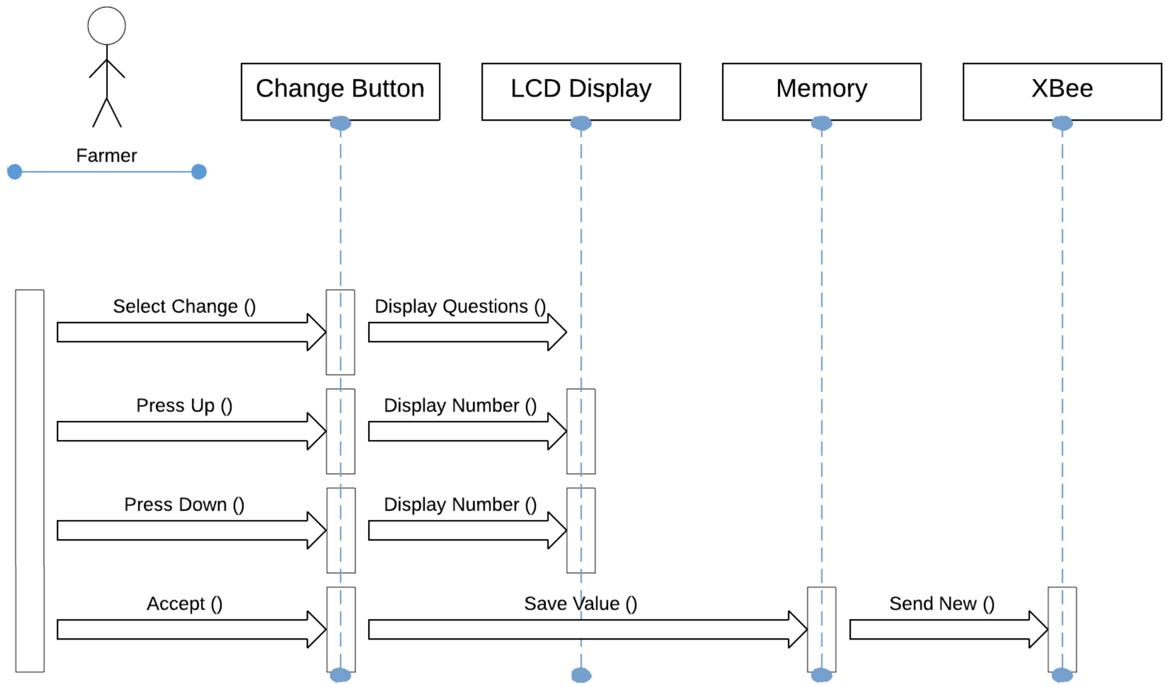


Figure H.7

This diagram represents when the user modifies or sets the values desired for the temperature and oxygen of the water to be. After the new values have been saved, it would send the data to the control system so it can use them.

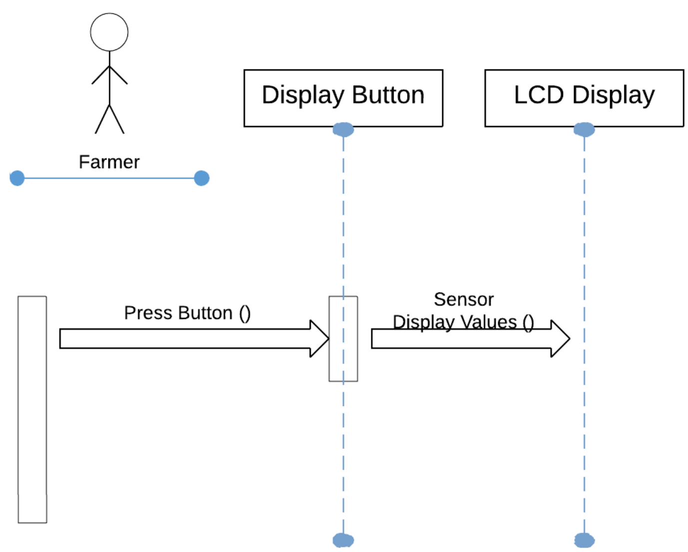


Figure H.8

This represents what happens when the “on button” is been pressed. It would turn on the LCD screen and display the sensors readings previously obtained.

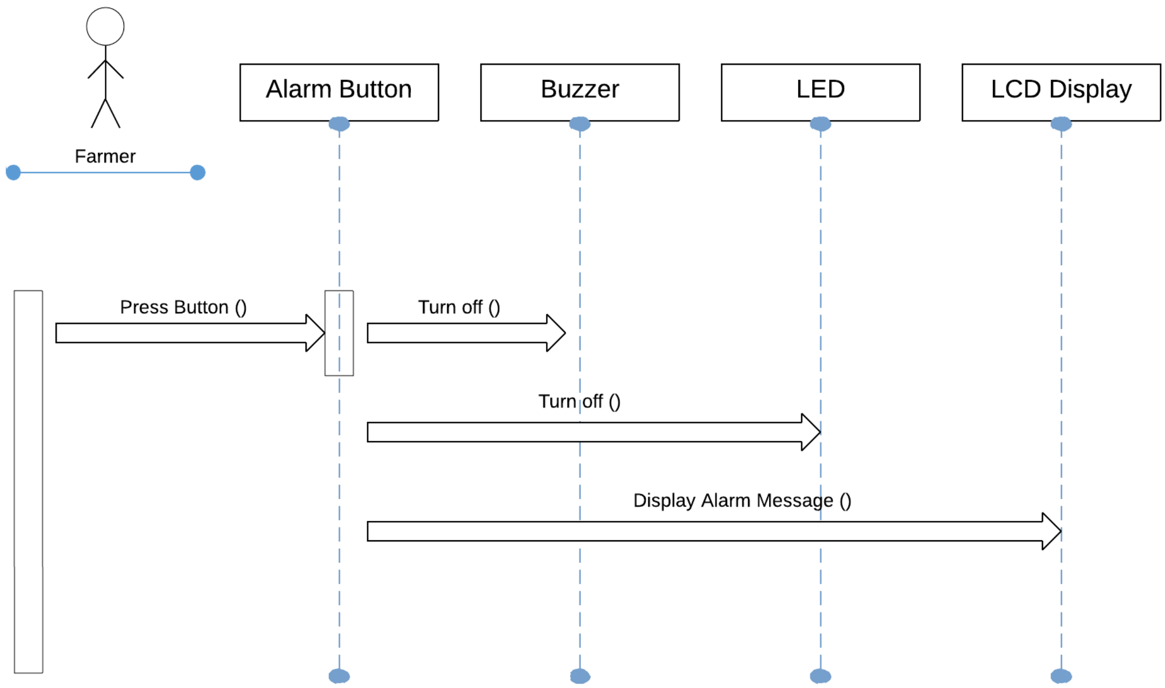


Figure H.9

This figure shows what happens when the alarm is on and the user wants to turn it off. Basically, it will display a message with the cause of the alarm and turn buzzer and red light off.

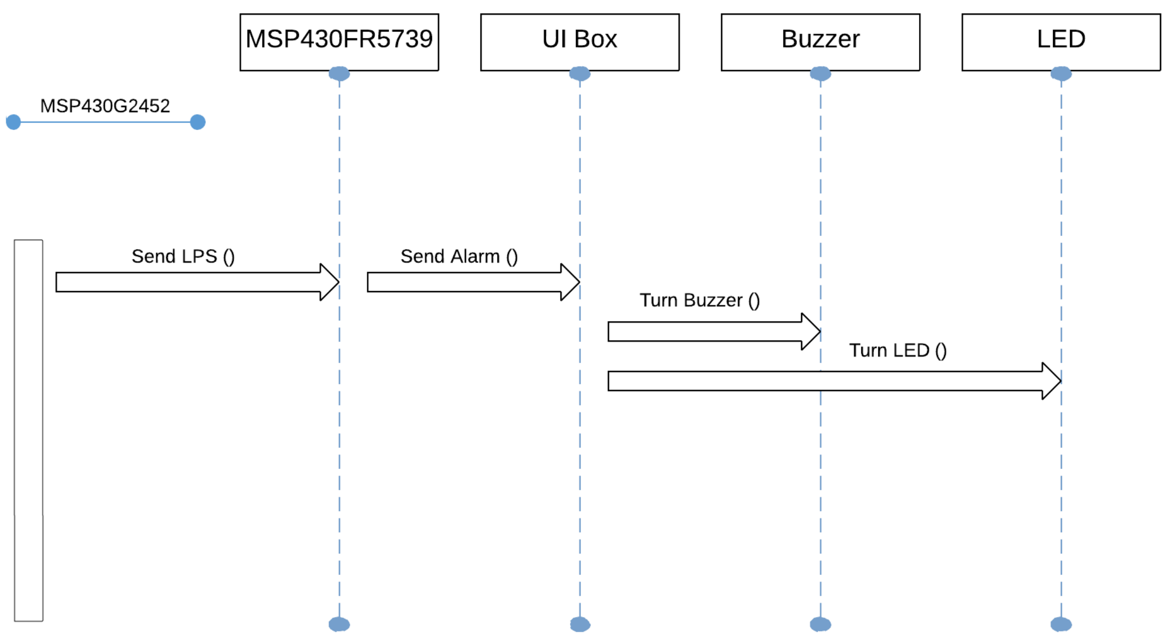


Figure H.10

The diagram shows what the procedure is when the power supply is depleted. This causes an alarm, sending the data to the UIBOX to alert the customer.

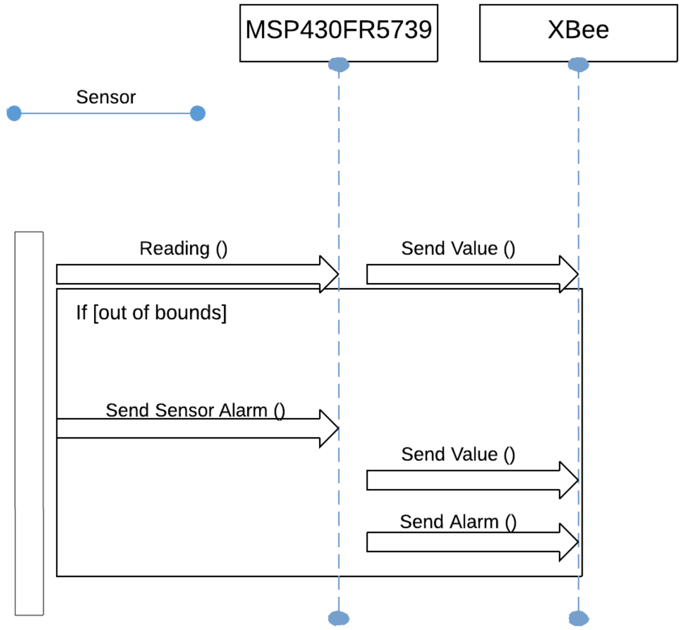


Figure H.11

Once the reading of the sensors is performed the values are sent via XBEE to the UIBOX. If the system was unable to maintain stability in the water it will send the values registered and the alarm signal for the UIBOX to read. This is a similar situation as the fig.H.10.

Appendix I – Testing Plan

Testing Plan (Hardware)

Each device module will undergo a series of tests.

These tests will be divided into two main test modules:

1. Electric Functionality

-Device powers up correctly.

-Device current and voltage levels on inputs and outputs are between bound limits.

-Device does not overheat after connection.

-Device enters sleep mode correctly and wakes up successfully (if applicable).

2. Main Functionality Test

-Device outputs the desired signal when given the corresponding input.

-Device processes input in reasonable amount of time.

-Devices that need calibration will be tested before and after to ensure proper calibration.

Component	***Testing Method***
Power Supply	Connect the circuit to the grid and a load to its output that exceeds the maximum power estimated.
MCU Module	Use a Logic Analyzer to verify the outputs at specific states.
User Interface	Simulate all the necessary conditions to launch the corresponding alarms and verify proper transmission of the wireless signal.
Oxygen Sensors	Alter oxygen conditions in the tank to track the behavior of the sensor and compare to results obtained from the Winkler Method*.
Oxygen Control	After altering oxygen levels verify if the control system activates to take proper action by pumping air into the tank and/or replacing the water.
Temperature Sensors	Alter temperature conditions manually by adding cold water to the tank and measuring temperatures manually (thermometer) to compare the accuracy of the measure obtained from the sensor.
Temperature Control	After altering temperature conditions verify if the control system activates to take proper action by heating the water and restoring optimal temperature conditions.

Table I.0 – Modular Testing Plan

After each module has been built and tested they will be put together as a whole system. Then it will undergo a Complete Functionality System Test that will ensure that all the modules correctly interact with one another and the elements will work together as a system.

Software Testing Plan - X-Bee Communication Module

Test Plan Identifier:

I. Module testing is according to Barefoot Inc. Project Proposal

Reference:

Appendix C: Standard

Introduction:

This is the individual X-Bee communication module test for the Aquaculture Maintenance System. This plan will address only those items and elements that are related to the communication module process. The focus of this plan is to ensure that the module will work properly and comply with the project requirements.

Test Item:

X-Bee Series 1 IEEE-802.15.4 Communication Module

Features to be tested:

X-Bee communication module for our project will be programmed and tested using RS-232 via serial communication with a HyperTerminal in the PC first in order to observe the procedure of the data sent and received to ensure it works and delivers proper information to project requirements. Later on, the MCU will be connected to it maintain proper work. The features to be tested include:

I. X-Bee is connected via serial communication with the PC.
II. X-Bee receives and sends packets to the PC via wires.
III. Set UART communication between the X-Bee module and the MCU.
IV. MCU sends wireless data to the system control interacting with the X-Bee.
V. MCU receives and stores information received from the X-Bee module.

Features not to be tested:

I. None

Approach:

I. The approach for the X-Bee communication module is to firstly connect the X-Bee modules between them and then establishes the serial connection with the Msp430 to send and receive data from the sensors and alarm.

Item Pass/Fail Criteria:

The module passes or fails the testing if the module fails to connect or the data transmission and reception fails to provide the data.

Features:

X-Bee Module is connected via serial communication with PC

Input: Write "AT" commands to establish communication with the module. The ATFR may be sent to the module to force software reset on the RF module.

Results: Characters are seen from the module shown

Pass: X-Bee correctly sends the same characters back to the PC.

Fail: Trash data is seen in the PC, or displays error.

X-Bee Module is connected via serial communication with MCU

Input: Write "AT" command to discover and report all modules on its current operating channel. The ATND may be sent to the module to report all PAN ID (Id parameter).

Results: Only a module matching the supplied identifier will respond.

Pass: X-Bee detects the other X-Bee module.

Fail: Unable to identify other module and get ID parameter.

X-Bee Module is connected via wireless communication to the other X-Bee Module

Input: Write "AT" commands to read signal strength with the other module. The ATDB may be sent to read the strength of the last packet received.

Results: Signal strength is above cero, because cero means no packets have been received.

Pass: X-Bee correctly receives packet with a -40dBm and the RF module's receiver sensitivity.

Fail: The number cero was read.

Appendix J– Economic Analysis

Costs	Budget	Actual Expenditure	Delta
Personnel Costs	$22,230.22	$22,230.22	0
Components and Parts Cost	$682.89	$780.00	$97.11
Total Expense	$22,913.11	$23,010.22	$97.11
Residual Budget	$7,907.56	$7,810.45	-$97.11

Table J.0 – Economic Analysis

Personnel costs maintained themselves right on target. Working hours stayed within the initially proposed hours of 300 per employee. With this the total expense for work hours is $22,230.22.

The costs for components and parts went up because of some items were not taken into consideration when building the prototype at the prototyping location and because of damaged components. The PVC tubes needed to build the prototype were not taken in consideration at the time of the initial budget proposal. However these are not part of the prototype device and will not be included in the component prices for the production of a device. The other aspect by which the cost of components and parts went up is because of damaged parts and components. These are parts that when building the prototype or testing it got damaged and stopped working properly and thus substituted by new parts. The parts were mainly damaged due to electrostatic discharges and current overload on the devices. New corrective action and precautions were made in the future. These boosted the cost for components and parts by approximately $70.

Due to the overhead expenses calculated initially the additional components bought did not create any major difficulties and the project was not compromised.

Appendix K – Task Progress and Gantt Chart

Component	Stage	Module Completion Level	Project Completion Level
Power Supply	Schematic Design	100%	15%
	Implementation	100%	
	Testing and Refining	100%	
	Total	**100%**	
MCU Module	Schematic Design	100%	30%
	Implementation	100%	
	Testing and Refining	100%	
	Total	**100%**	
User Interface	Schematic Design	100%	5%
	Implementation	100%	
	Testing and Refining	100%	
	Total	**100%**	
Oxygen and Temperature Sensors	Schematic Design	100%	5%
	Implementation	100%	
	Testing and Refining	100%	
	Total	**100%**	
Water Heater Module	Schematic Design	100%	15%
	Implementation	100%	
	Testing and Refining	100%	
	Total	**100%**	
Valves and Pumps Control System	Schematic Design	100%	5%
	Implementation	100%	
	Testing and Refining	100%	
	Total	**100%**	
System Integration	Implementation	100%	25%
	Testing and Refining	100%	
	Total	**100%**	
		Total	**100%**

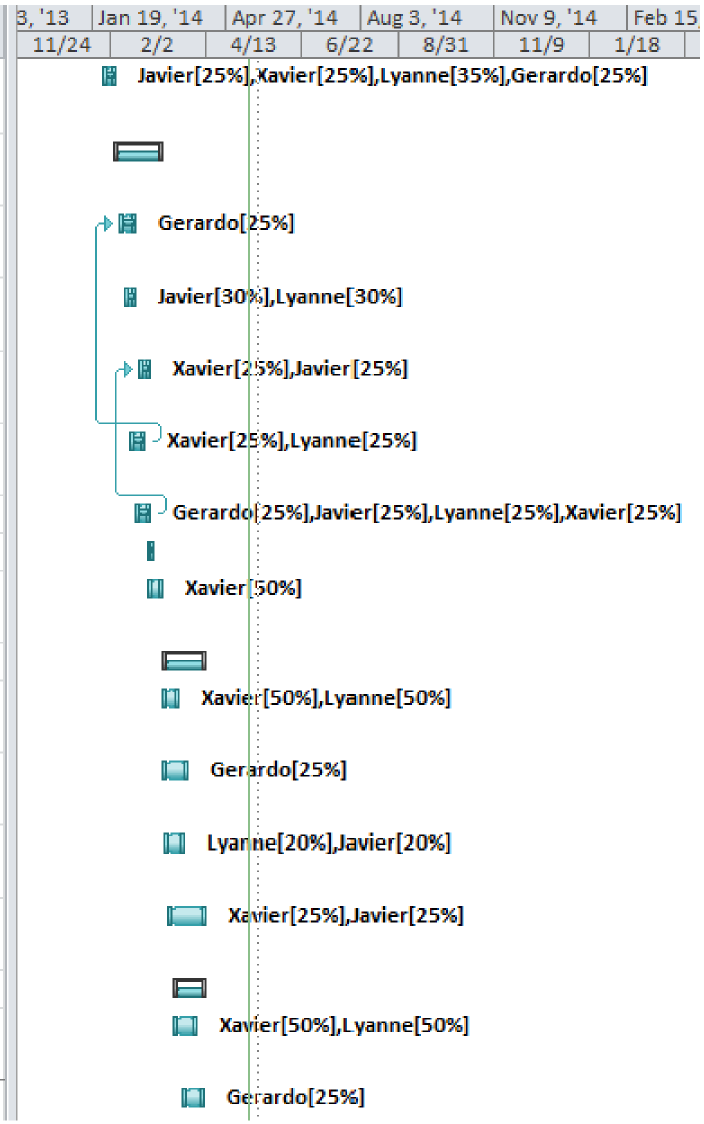
Table K.0 - Metrics to Assess Task Progress

Task		*Completion (%)*	*Comments*
Detailed System Specs and Module Designs	UI-Box	100%	• System specs were changed during this process. • Modules were designed separately.
	Main System	100%	
	Power Supply	100%	
Module Implementation and Testing	UI-Box	100%	• Each module was tested separately. • Identify errors and make integration easier.
	Main System	100%	
	Power Supply	100%	
Full Integration and Testing	Automatic Maintenance System	100%	• Complete module testing. Readings were properly displayed. Errors were found and dealt with.

Table K.1 Shows project completion

Gantt Chart

	Task Name	uratio	Start	Finish
1	Detailed System Specification	4 days	Wed 1/29/14	Mon 2/3/14
2	**System Design and Simulations**	**30 days**	**Wed 2/5/14**	**Mon 3/10/14**
3	Detail Design Module - Power Supply	8 days	Mon 2/10/14	Tue 2/18/14
4	Detail Design Module - Sensors	4 days	Fri 2/14/14	Tue 2/18/14
5	Detail Design Module - Control System	5 days	Mon 2/24/14	Fri 2/28/14
6	Detail Design Module - User Interface	7 days	Tue 2/18/14	Mon 2/24/14
7	System architecture	8 days	Fri 2/21/14	Fri 2/28/14
8	Design Acceptance	1 day	Mon 3/3/14	Mon 3/3/14
9	Order Components	7 days	Mon 3/3/14	Mon 3/10/14
10	**Implementation**	**21 days**	**Thu 3/13/14**	**Thu 4/10/14**
11	Implementation Module User Interface Panel	7 days	Thu 3/13/14	Fri 3/21/14
12	Implementation Module Power Supply	12 days	Thu 3/13/14	Fri 3/28/14
13	Implementation Module Sensors	8 days	Fri 3/14/14	Tue 3/25/14
14	Implementation Module Control System	19 days	Mon 3/17/14	Thu 4/10/14
15	**Testing & refining**	**15 days**	**Fri 3/21/14**	**Thu 4/10/14**
16	Testing Module User Interface	11 days	Fri 3/21/14	Fri 4/4/14
17	Testing Module Power	9 days	Fri 3/28/14	Wed 4/9/14



	Task Name	uratio	Start	Finish
18	Testing Module Sensors	21 days	Mon 3/10/14	Tue 4/8/14
19	Testing Module Control System	11 days	Thu 3/27/14	Thu 4/10/14
20	Code Testing	9 days	Mon 3/31/14	Thu 4/10/14
21	**System Integration**	**12 days**	**Fri 4/11/14**	**Mon 4/28/14**
22	Integration Modules Sensors and Control	9 days	Fri 4/4/14	Wed 4/16/14
23	Integration Modules Power Supply with system	6 days	Wed 4/16/14	Wed 4/23/14
24	Full integration	3 days	Wed 4/23/14	Fri 4/25/14
25	Integration Testing	2 days	Fri 4/25/14	Mon 4/28/14
26	System Demo	1 day	Mon 4/28/14	Mon 4/28/14
27	**Delivery**	**82 days**	**Tue 2/4/14**	**Tue 5/20/14**
28	Progress Report #1	7 days	Mon 2/24/14	Sun 3/2/14
29	Progress Report #1 Presentation	2 days	Mon 3/3/14	Tue 3/4/14
30	Happy Hour #1	5 days	Mon 3/10/14	Fri 3/14/14
31	Happy Hour #2	4 days	Mon 4/7/14	Thu 4/10/14
32	Happy Hour #3	4 days	Wed 4/30/14	Mon 5/5/14
33	Final Presentation	1 day	Thu 5/8/14	Thu 5/8/14
34	Return equipments	1 day	Fri 5/9/14	Fri 5/9/14
35	Final Report	8 days	Fri 5/9/14	Tue 5/20/14
36