# Automated pH Monitoring System

To be interfaced into Environmental Control Systems

April 25, 2013

WORCESTER POLYTECHNIC INSTITUTE

A Major Qualifying Project Report

In partial fulfillment of the

Degree of Bachelors of Science in

Electrical and Computer Engineering

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Project Number: MQP-SJB-4A12

# Acknowledgements

I would like to thank Professor Stephen J. Bitar not only for his knowledge and guidance throughout my Major Qualifying Project but also for sparking my interest in the Electrical Engineering Field. In Microelectronics I, his fun teaching style in combination with his overwhelming labs taught me the dedication necessary to survive in the Electrical and Computer Engineering Department at WPI. His love for the field and for his students is apparent to everyone that has the pleasure to meet him.

I would also like to thank Chris Walker, a graduated member of WPI's Electrical and Computer Engineering Department, and Corinne Nawn, a junior member of WPI's Computer Science Department, for taking time to attempt to trouble shoot the code intended to program the PIC microcontroller.

# Abstract

The purpose of this project was to assist greenhouse monitoring systems by automatically checking and maintaining the pH levels of nutrient enriched water solution used in soil-less agriculture systems. To accomplish this goal a pH sensor was interfaced with a PIC microcontroller. Initial tests were not able to be tested due to the time constraint of the project and the lack of a working program to control the system. Further work is essential to complete a working prototype.

## Executive Summary

Citizens of the United States were inspired to plant gardens on their property during the world wars to assist in the nation's food supply. During these times many families were able to rely on the home grown gardens, known as victory gardens, as a produce supply. Today citizens are fighting a different battle. That is the battle of fresh and nutrient enriched fruits and vegetables. More often than not the produce supplied by your local grocery stores has been shipped many miles before reaching the selves. The produce is also manufactured with the quantity of supply in mind instead of the quality. Substitutes to these goods are organically grown produce without the use of pesticide and growth hormones. However organic produce is quite expensive and is often times out of many the consumers' budget.

Growing produce at home is a solution to the grossly manufactured produce and the overpriced organic produce. Home grown produce has many advantages such as lower grocery bills, fresh and nutritious produce directly to their dinner table and complete control over the chemicals used to grow the produce.  However home grown gardens do have their disadvantages. Most crops can only be grown in certain climates during certain times of the year. The rise of Controlled Environment Agriculture (CEA) proposed a new direction for agriculture. CEA is an agriculture technique which allows for the growth of plants in controlled conditions. The conditions of greenhouses can be set to the optimum growing conditions for any plant year round. This spark to a new technique of growing produce has increased rapidly. Greenhouses can be implemented in ways ranging from rooftops to an addition to a home to abandon fields and parking lots.

For the healthy growth of plants light, carbon dioxide, water and mineral nutrients are needed. In the early 1800's scientists discovered that plants absorb mineral nutrients as inorganic ions in water. They also found that soil is not essential to plant growth but it provides a mineral nutrient reservoir as well as a place for plants' roots to anchor. From this discovery researchers began to develop soil-less agriculture. There are many types of soil-less agriculture; however the most popular are hydroponics, aeroponics and aquaponics. Hydroponics is the method of growing plants without the use of soil. The plants are supplied a nutrient enriched water source and are grown in inert medium. This inert medium can be composed of gravel, clay stone or coconut coir but as soil do not supply any nutrients to the plants. They do however supply structural support for the plants healthy growth. Aeroponics is very similar to hydroponics although this technique does not involve an inert medium. Aeroponics suspends the plants' roots in an enclosed chamber. This chamber is filled with a mist of the nutrient enriched

water solution. Aquaponics is the combination of raising an aquatic animal culture and hydroponics, which can be used to create a food and plant production system. The aquatic animal culture usually consists of fish but can also consist of snails or crayfish. The fish waste provides as a food source to the plants and the plants clean the water for the fish to continue to use.

Soil-less agriculture is becoming much more popular. The trouble with soil-less agriculture comes with human error. If the nutrient enriched solution is supplied to the plants at the wrong pH then the grower can be poisoning their plants without any knowledge of it happening. As the plants are supplied a poisonous mixture of nutrients they begin to become malnourished and eventually will die. Hobbyist growers, who are often growing less than one hundred plants, cannot afford to allow there plants to become malnourished. Even if the plants they do survive they will not produce many if any crops. A similar scenario goes for commercial grows. Except in this case knowing the pH of the nutrient enriched solution being supplied to the plants can be the difference in having the maximum crops produced and having the entire crop culture perish. The goal of this project is to provide an integrated solution to monitor the pH of the nutrient enriched water solution being supplied to plants in all soil-less agriculture systems.

## Project Goals

The main goal of this is project is to design an integrated circuit to automatically test the pH of the nutrient enriched water source used in soil-less agriculture techniques. The system should be capable of accurately reading the pH of the water solution as well as initiating the steps to maintain the solution within the optimal pH range for plant growth of 5.5 – 7.5. The system should be adjustable as each plant has a slightly different optimal range for plant growth. Below is a list of the design requirements:

1. 100% Stability- Meaning the sensing module would be able to calibrate the sensors and accurately measure the solutions pH.
2. Interface pH sensor with a microcontroller- Meaning electrically wiring the pH sensor to the microcontroller
3. Up to 100 nodes- Meaning to have the ability to implement 1oo sensing modules.
4. Accurate calibration of pH sensor- Meaning initial calibration of sensor are accurate
5. Accurate sensors for monitoring pH of nutrient enriched solutions- Meaning after calibration the sensor will need to accurately measure the pH of any nutrient solution.

6. Ability to add and subtract nodes with ease- Meaning the ability to add and subtract sensing modules without complication.

## Design Overview

The system level block diagram for the sensor is shown below in Figure 1. The individual components, the decision making behind their selection and how they were interfaced will all be covered within the following report. A complete list of the parts used in the transformation of the system is shown in table 3.

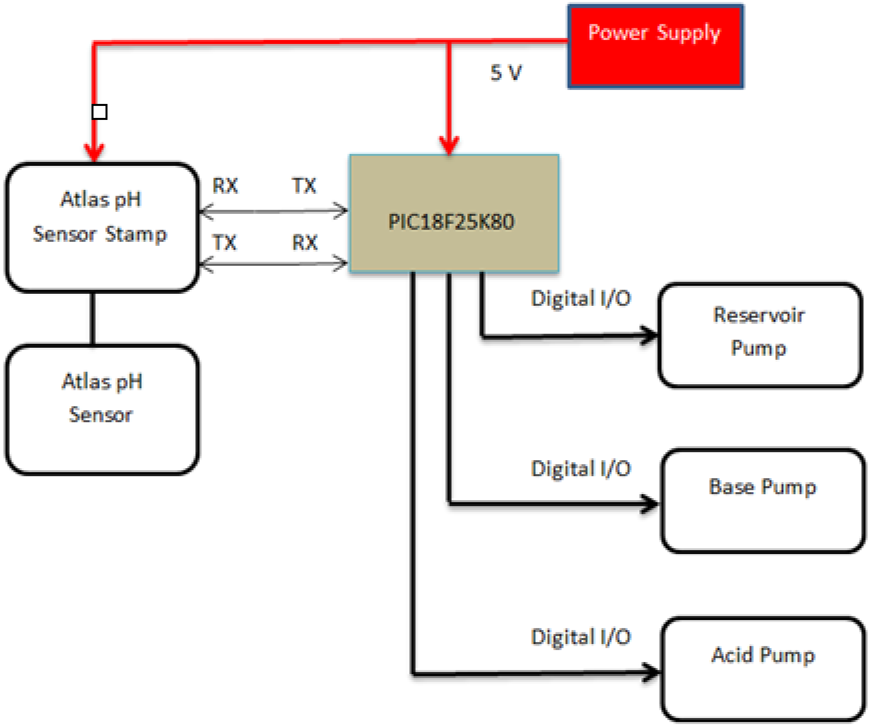

Figure 1: System Level Block Diagram

The PIC18F25K80 microcontroller (PIC) is used as the brain of this system. The PIC communicates with the pH sensor stamp which converts the pH sensor's data using a combination of two amplifiers and an A/D converter to determine the pH of the nutrient enriched water solution. From this data sent to the PIC, the PIC determines which control outputs to drive. All of the outputs would be connected to power relays to either pump acidic or basic solution into the main reservoir or to pump the main reservoir's nutrient enriched water, with the correct pH, into the feed lines. The feed lines feed directly to the plants. These small modules could be placed within different reservoirs for different plants. As each plant has an optimum pH range at which maximize growth this can be seen in table 2. This would allow for multiple plants to be grown in parallel systems.

## Conclusions

The project was remotely a success: out of the six project goals three of them were successfully implemented. The stability of the system was not able to be calculated without the programming of the microcontroller. There is not a limit on the amount of nodes that can be used within any system or parallel systems. Additional nodes can be easily implemented. The system was not able to be accurately calibrated which did not allow for accurate sensor readings to monitor the pH of the nutrient enriched solution.

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# Glossary of Terms

| | |
|---|---|
| CEA | Controlled Environment Agriculture |
| PIC | PIC18F25K80 Microcontroller |
| MPG | Miles per Gallon |
| GPM | Gallons per Minute |
| PSI | Pounds per Square Inch |
| CPU | Central Processing Unit |
| RAM | Random Access Memory |
| ROM | Read Only Memory |
| I/O | Input/Output |
| RX | Receiving Line |
| TX | Transmission Line |
| EC | Electrical Conductivity |

# 1.0Introduction

Citizens of the United States were inspired to plant gardens on their property during the world wars to assist in the nation’s food supply. During the world wars a majority of the males in families were drafted to the armed forces and deployed overseas. This left many women and young children to survive on their own. Many families were able to rely on the home grown gardens as a produce supply. Today citizens are fighting a different battle. That is the battle of fresh and nutrient enriched fruits and vegetables. More often than not the produce supplied by your local grocery stores has been shipped hundreds even thousands of miles before reaching the selves. The produce is also manufactured with the quantity of supply in mind instead of the quality. Substitutes to these goods are organically grown produce without the use of pesticide and growth hormones. However organic produce is quite expensive and is often times out of many the consumers’ budget.

A solution to the grossly manufactured produce with the use of pesticides and growth hormones and the overpriced organic produce is to grow produce at home. It would be very difficult for an amateur grower to produce enough fruits and vegetables to cater to their needs completely. Although a home grown garden can supply some of the produce needs of the grower; which will cut down grocery bills, bring the freshest and most nutritious produce directly to their dinner table as well as allow the grower to have complete control over what chemicals are used in the growth of the produce.  However home grown gardens do have their disadvantages. Most crops can only be grown in certain climates during certain times of the year. The rise of Controlled Environment Agriculture (CEA) proposes a new direction for agriculture. CEA is an agriculture technique which allows for the growth of plants in controlled conditions. These conditions can be set to the optimum growing conditions for any plant. Greenhouses can contain these conditions, which allow plants to grow within optimal conditions year round. This spark to a new technique of growing produce has increased rapidly as these greenhouses can be implemented in ways ranging from rooftops to an addition to a home to abandon fields and parking lots. The movement to home grown gardens is on the up rise and has started to make its way towards self-sufficiency.

## 2.0 Background

For plants to grow they need light, carbon dioxide, water and mineral nutrients. Plants use these resources to create sugar or food. A nutrient enriched water source is simply water doped with mineral nutrients called micronutrients or trace elements. The mobility of the nutrients is determined by the pH of the solution. When these micronutrients become more mobile they are absorbed by the plants rapidly and in excess of what the plant actually needs. This results in toxicities in the plant (shown by a low pH measurement). When the micronutrients are less mobile the plant has trouble absorbing the nutrients, which then leads to plant deficiencies (shown by a high pH measurement) [2]. Knowing the mobility or the pH of the nutrient enriched water is very important when growing a small quantity of crops as well as when growing a large quantity of crops. Keeping a control over the pH of crops for a large farmer can be the difference between making a substantial profit and not creating enough revenue to keep the business running for the next year.

### 2.1 What is pH?

pH is a measurement of the acidity or basicity of a mixture or solution. The pH range is from 0 meaning most acidic to 14 meaning most basic [1]. The most common pH range is from 4 to 10, which are shown below in Figure 1.

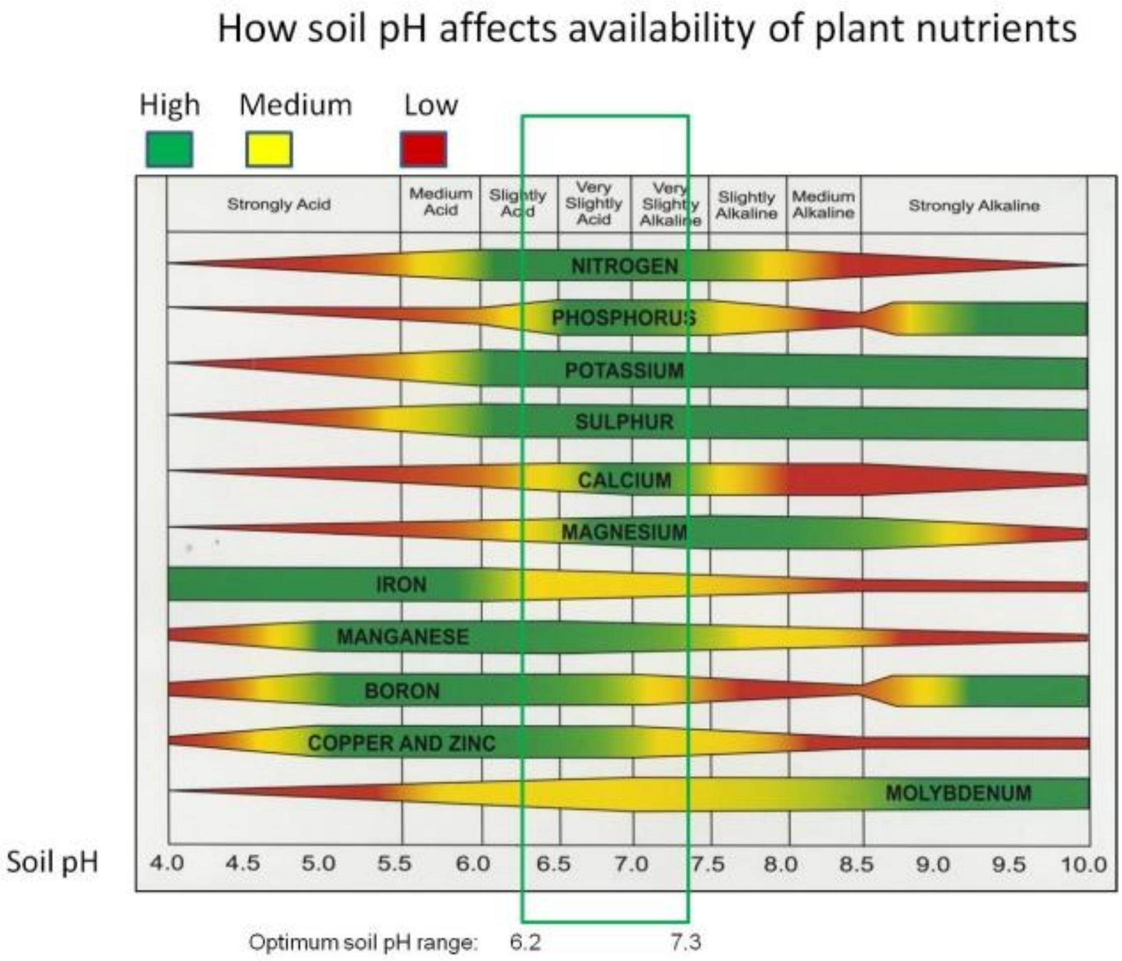


Figure 2: pH Range from 4 – 10 [13]

A pH measurement is the representation of the number of hydrogen ions in solution. A logarithmic scale is used to measure pH. The scale works in increments of 10 times more hydrogen ions then that of the previous increment. For example, a solution with the pH of 6 has 100 times more hydrogen ions than a solution with a pH of 8 [3]. To show the ranges of pH in a more general sense refer to Figure 2.

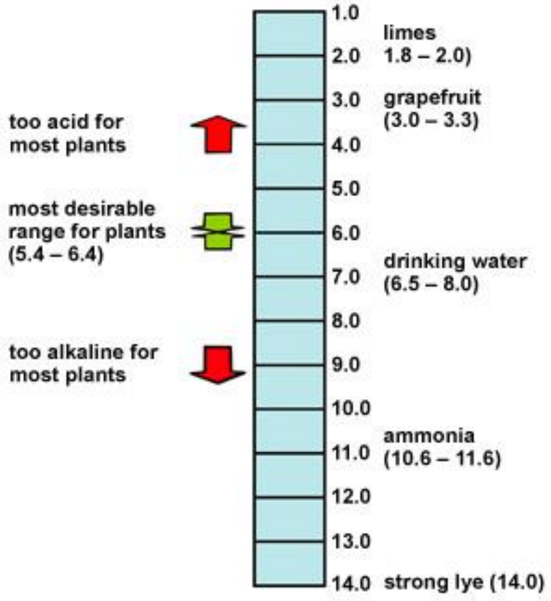


Figure 3: pH levels [2]

The measurement of pH is represented by a balance between hydrogen and hydroxyl ions. A lower pH represents a higher concentration of hydrogen ions relative to hydroxyl ions. A higher pH represents a higher concentration of hydroxyl ions relative to the hydrogen ions [2]. Every plant species has a preferred pH but an average the optimal range for maximum growth is 5.5 – 7.5.

## 2.2 Types of Soil-less Agriculture

Researchers in the early 18th century discovered that plants absorb mineral nutrients as inorganic ions in water. Researchers also found that soil is not essential to plant growth as it actually acts as a mineral nutrient reservoir and an anchor for the plants. Hydroponics is the method of growing plants using a nutrient enriched water source without the use of soil. Instead of soil the plants are grown in an inert medium such as gravel, clay stones and coconut coir. These mediums do not supply any nutrients to the plants but much like soil they supply the plants with a place to anchor as well as a reservoir for the nutrient solution. However hydroponics is not the only type of soil-less agriculture, aquaponics and aeroponics are also very popular techniques. Aquaponics is the cultivation of plants and aquatic animals in a recirculating environment. The fish are fed by the farmer and the fish waste provides a food source for the plants. The plants clean the water for the fish to continue to live in. Aeroponics removes the use for a medium or a place for the plants to anchor themselves. Instead the plants a suspended leaving their roots exposed. The roots are sprayed with a mist of the nutrient enriched solution.

### 2.2.1 Hydroponics

Hydroponics technically means working water. This is stemming from the Latin words “hydro” meaning water and “ponos” meaning labor. To most of us, hydroponics means the growth of plants using a nutrient enriched water source without the use of soil [4]. There are many advantages that go along with using a hydroponic growth system. These advantages include the conservation of water, the complete control of what nutrients are supplied to the plants and stable plants with much higher yields. Other advantages consist of less disease risk to the plant culture, the lack of insects and other organisms damaging the plants as well as an easier harvest period. Without the damage from insects and other pests the plants will not need to be influenced by pesticides and other harmful chemicals [5]. In figure 4 below you can also see how close plants can be grown to one another using hydroponics.

Figure 4: Example of a Hydroponic System [6]

Although hydroponics does have some disadvantages. One disadvantage is unlike soil gardens, hydroponic gardens need to be cared for every day. Other disadvantages range from large initial investments, high rates of failure for amateurs and power outages can quickly kill the plants [7]. Within days without the nutrient solution your entire crop can shrivel up and die.

### 2.2.2 Aeroponics

In 1983, Richard Stoner filed a patent for the first ever microprocessor interface to deliver a nutrient enriched mist into an enclosed aeroponic chamber. He is known to many of his colleges as the “Father of American Aeroponic Technology” [8]. Aeroponics is the process of cultivating crops in the air or mist environment without the use of soil or any other aggregate medium. In aeroponic systems plants are secured to a structure to allow their roots to grow freely. The roots are contained within a nutrient enriched mist filled chamber [9]. Figure 5 shows a detailed block diagram of an aeroponic system.

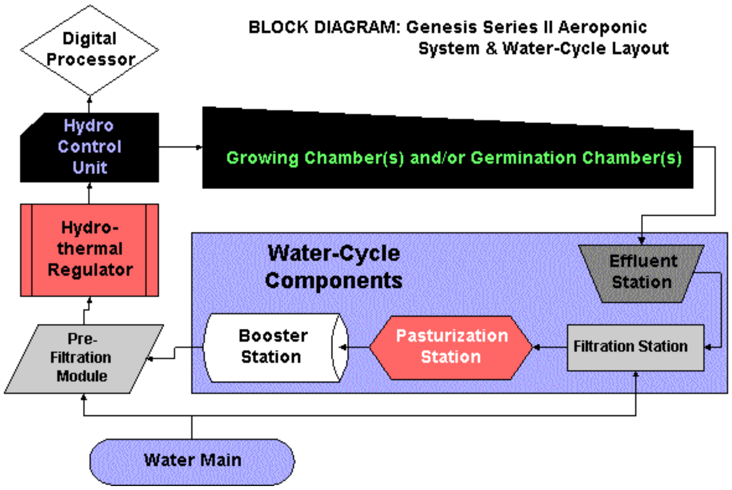


Figure 5: Block Diagram of an Aeroponic System [9]

In aeroponics the roots are able to access much more oxygen then in hydroponics and aquaponics. Increased aeration of the nutrient enriched solution delivers more oxygen to plant roots. This stimulates growth within the plant and helps prevent against pathogen formations on the plants' roots [10].

The advantages to aeroponics make it seemingly obvious that it is the most efficient soil-less agriculture system. Aeroponics use 10% of the water needed for hydroponics and aquaponics because of the use of mist. Also in aeroponics the use of a medium is nonexistent, thus plants can be placed closer together and plants can be removed easily at first sign of disease or infection. Also plants grow much quicker and are much healthier than with the use of any other growing system. Aeroponics do not have a long list of disadvantages, but the major disadvantage to an aeroponic growing system is any failure in the system that stops the flow of nutrient enriched mist will result in a quick death to the entire plant culture [9]. Figure 6 below shows a detailed example of an aeroponic system.

**Figure 6: Detailed Example of an Aeroponic System [10]**

### 2.2.3 Aquaponics

The first development of aquaponics is not exactly known, most references say that China and Thailand who cultivated rice in paddy fields in combination with the cultivation of fish were the first to use the technique. The development to the modern aquaponics system is attributed to the New Alchemy Institute and Dr. Mark McMurty et al at the North Carolina State University. Aquaponics is the combination of a closed cycle between the cultivation of fish and crops. The system works like any swamp or fresh water source with vegetation growth and aquatic life. As the fish consume small organisms and other food sources they release fecal matter into the water. The plants use the nutrients from the fecal matter as a food source which in turn cleans the water source for the fish to then use as a habitat [12].

The development of commercial aquaponics is a bit more complex. The system consists of two main parts, with the aquaculture part used to raise aquatic animals and the hydroponics part for the growth of plants. Although the system consists primarily of these two parts, there are generally several components that are also used to complete the system. These components' functions consist of removal of solid waste, adding bases to neutralize the acids within the fecal matter and maintaining the oxygen saturation of the water source. Figure 7 below shows a diagram of an aquaponic system.

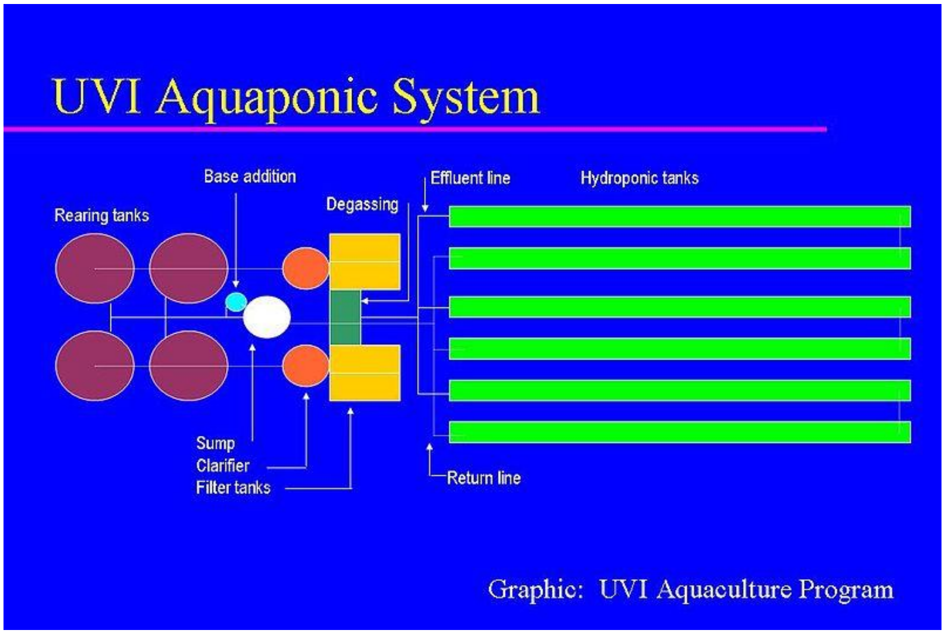


Figure 7: Diagram of an Aquaponic System [13]

The advantages of aquaponics are evident with the reuse and recycling of water, which keeps water waste low. Also with the use of organic fertilization of plants through the natural fish secretions in addition to the elimination of solid waste disposal from intensive aquaculture is a huge benefit to the environment. This system as with the others reduces the need for land to produce crops [14]. The disadvantages much like the other systems include a large initial cost as well as any complications with the system, such as power failure or pipe line blockage, can lead to complete loss of fish stock and crop culture.

### 2.2.4 Summary

Each one of these systems benefit the environment, save land and space, grow healthier plants with a much smaller risk of disease within the plant culture and create high yields for the entire crop culture. These benefits can help a commercial farmer by maximizing profits and minimizing costs and can help for a homeowner grow fresh and delicious produce at home.

## 2.3 Scales of Soil-less Agriculture

Soil-less agriculture has grown over the past 200 years from an experimental idea of growing crops with less water waste and higher yields into a range from enormous industries to small family gardens. This range is the difference between large businesses to the growth of fresh home grown produce. This idea of soil-less agriculture has been expanding sense it was discovered and it will continue to grow.

### 2.3.1 Family/ Hobby Scale

A garden grown in your back yard can produce some of the freshest, tastiest and healthiest produce compared to buying from a local grocery store. Most of the produce that hits the shelves at your local market has traveled many miles over a period of several days. Other benefits to growing your own produce are reduced grocery costs and knowing exactly what goes into your produce thus making a healthier choice for a family. This in combination of the benefits of soil-less agriculture can prove to be a great hobby while gaining all of the additional benefits.

Hydroponic systems at the hobby level can be purchased in full online. These systems can grow roughly 20-50 leaf crops through one cycle. These systems are built in columns which allow the hobbyist to grow a variety of produce or to have multiple stages of the same type of plant.  An example of a hydroponic system that can be purchased from homehydrosystems.com is shown in figure 8.

Figure 8: Hydroponic System [15]

This system includes stands for large plants with heavy crops, reservoirs for smaller leafy greens and pumps to cycle the water in and out of the plants reservoirs to the storage bins. This system can be assembled for a cost of $400.00 [15].

Aeroponics systems at the hobby level are very similar to the hydroponic systems. They can support roughly the same amount of plants and full systems can be purchased online as well. The systems come with very similar parts except the aeroponics implement a spray mechanism to fill the enclosed chambers with nutrient enriched mist. An example of this system is shown below in figure 9.

**Figure 9: Aeroponic System [16]**

This system can support the growth of 18 plants at once. It can be purchased from nehydro.com for $395.95. This system contains a 17-gallon reservoir and is normally used to grow smaller plants such as lettuce and basil [16].

Aquaponic systems are similar to the others types of soil-less agriculture in the fact that it is possible to purchase a full system. Although the systems are much more expensive than the others as they consist of more parts. They include large tanks to raise the fish culture, reservoirs to grow plants, feed lines and return lines for the water and the pumps to control the water within the system. An example of an aquaponic system for sale is shown in figure 10.

Figure 10: Aquaponic System [17]

This system is for sale on aquaponicsusa.com for $1795.00. It contains a 120 gallon round fish tank, two 11 $ft^2$ grow beds, two grow tables, complete plumbing and pumps [17]. These grow beds can maintain any type of plant from leafy greens to large plants with heavy fruits such as tomatoes.

### 2.3.2 Commercial scale

Given the number of advantages of hydroponics it is not a surprise that hydroponic techniques are increasingly finding favor for commercial food production. Due to the efficiencies and the ability to produce healthy crops, the greenhouses that are used to commercially produce hydroponics yield 20 – 25 percent more than a greenhouse using traditional techniques. In some particular crops the hydroponic methods can produce up to twice as much as the traditional methods. The use of hydroponics in producing a wide variety of lettuce and peppers has seen growth of producing more than 4 times then using traditional methods. The idea behind it is quite simple; with hydroponics commercial farms can grow better quality food easier, faster and more efficiently.

Hydroponics and aeroponics fall into the same category of efficient commercial production of produce. Although aeroponics uses less water than hydroponics they both consume a similar amount of space to grow the same range of produce. The largest disadvantage to these systems is the initial investment needed to implement a commercial system. The initial investments for this scale of a greenhouse system are quite expensive. A greenhouse alone can cost over $100 per square foot [18]. That is without the implementation of a hydroponic system.  However the return on investment of hydroponic or aeroponic systems is much higher than the traditional methods because the commercial grower can optimize up to 90% of a greenhouse's space using soil-less agriculture. This compared to the on average less than 40% with tradition growing methods. With hydroponics crops can grow on top of one another to maximize plant production.

Figure 11: Commercial Hydroponics System [19]

Figure 11 shows how efficient hydroponics is with conservation of space. Figure 12 shows a tradition greenhouse system with soil agriculture.

Figure 12: Soil Agriculture Greenhouse [20]

As we can see from figure 12, the space of this greenhouse is not optimized as it is in figure 11.

Commercial aquaponics can be chosen by farmers who do not have abundant resources. Aquaponics is a closed loop system which means there is virtually no loss or wasted water. Systems that do not recycle their water use anywhere from 5 to 10 thousand gallons of water per pound of produce produced. This can lead to large problems for farmers in areas with limited water resources. Another advantage to aquaponics over the other soil-less agriculture methods is it is producing more than just crops. It also can produce fish. A typical commercial aquaponic system grows large heads of lettuce. These systems can produce almost 7,500 pounds of fish while producing almost 200,000 heads of lettuce per year. However aquaponics is not the preferred method in commercial production of produce. This is mainly due to the lack of experienced personnel and the difficulty in sustaining the complex system [21]. Aquaponics is the most efficient type of soil-less agriculture in terms of water consumption. However it does not have the same space conservation as hydroponics and aeroponics have which gives them the upper hand in the commercial market.

## 2.5 Justifications

There are many justifications behind growing crops using soil-less agriculture instead of using the traditional in soil growing techniques. Soil-less agriculture conserves water and other resources used to grow crops. Plants within soil-less agriculture systems can be grown closer together which saves space. There is less of a chance of disease and infestation within a soil-less crop culture. Also plants' roots do not need to expand as far to reach valuable nutrients thus the plant will grow larger, shown below in figure 13.

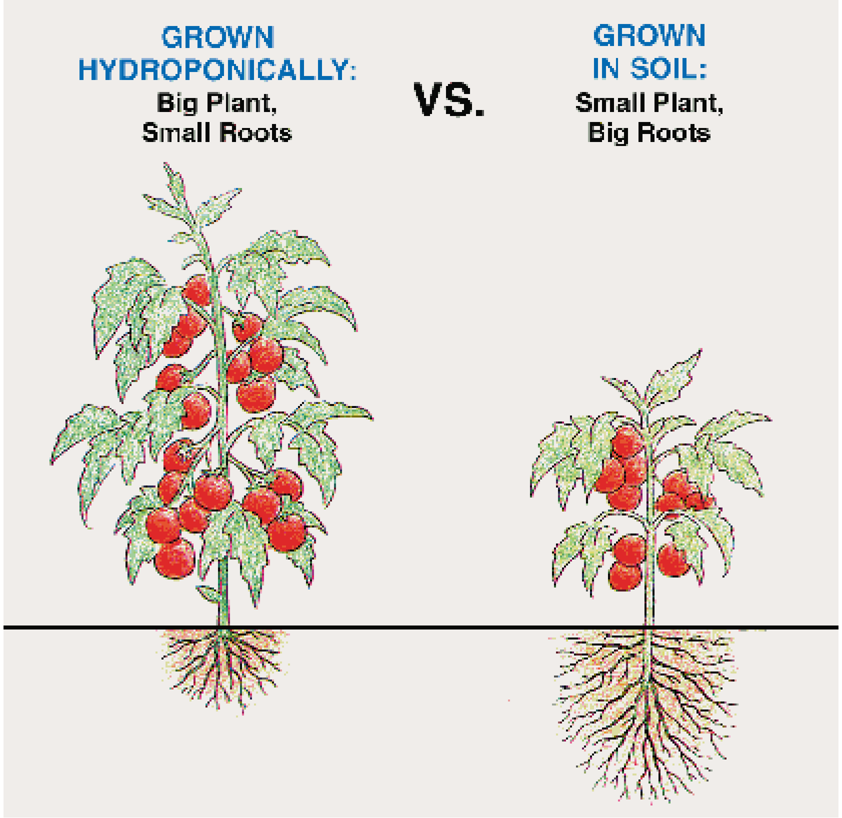


Figure 13: Hydroponic Roots vs. Soil Roots [22]

There are also many justifications for growing your own crops within a home or greenhouse as well. These justifications include reducing your environmental impact, improving the overall health of produce, money savings on grocery bills and reducing food waste. All of these justifications are the advantages to growing your own food within your own home. Also If a greenhouse is implemented the owner can benefit by growing their own produce year round [23].

Reducing environmental impact has been an ongoing struggle all over the world today. As more people grow their own produce in soil-less agriculture systems less pesticides and herbicides will be used. As a result to this there will be less of an impact on polluting the earth’s land and water sources. The earth’s ozone is another main concern here. This does not solely include creating vehicles with a higher mile per gallon (MPG). People can reduce their carbon foot print by growing their own produce as well. If more people grew their own produce less produce would need to be packaged and shipped across countries and even across the world. Without shipping so many produce goods, fossil fuels can also be spared.

Fossil fuels are not the only resource being spared with soil-less agriculture systems. Generally hydroponic systems use 5 – 10 % of the water used in soil agriculture to produce the same amount of crops. A study found that is takes about 70 gallons of water to produce a single pound of lettuce using soil techniques versus only 3 gallons of water to produce a pound of lettuce using hydroponic techniques. The conservation of water is coupled with the conservation of nutrients the plants need to grow [23]. As the nutrient enriched water source is supplied to a plant in a hydroponic system the plant absorbs most of the nutrients out of the water solution. Once the plant has taken most of the nutrients the water is cycled back into the main reservoir. Sense the water recycles and nutrients the plant did not absorb are also recycled and supplied back to the plant at a different time. This cycle insures that all of the nutrients are used and very little, if any are wasted. It is much easier for plants, meaning they use much less energy, to receive nutrients from a hydroponic system versus a soil system. When plants use less energy to absorb nutrients they grow, thus becoming much healthier. Healthy plants generate much healthier and larger yield to the grower.

Farmers have begun to adopt the idea of growing crops in greenhouses using soil-less agriculture techniques. Greenhouses can be built easily. With the combination of hydroponics the farmer can shorten grow cycles and create revenue more quickly. Also greenhouses can be built in a large variety of places. As greenhouses become more popular more potential farmers will begin to generate crops to sell locally [24]. As more greenhouses are built, automated environmental systems for green houses will arise. As more automated environmental systems are being developed, the developers will search for automated sensors to control all aspects of the greenhouse environments, including automated pH sensors.

## 2.5 Problem Statement

Each one of the soil-less agriculture systems relies on the nutrient enriched water source to provide the plants with the nutrients they need. If the water source is not at the correct pH level the nutrient enriched water can actually be harmful to the plants. A solution provided to the plants with a low pH can lead to toxicities within the plant and a solution provided to a plant with a high pH can cause deficiencies within the plant. Many times toxicities and deficiencies in plants are easy to see. They can be seen by browning of the leaves, leaves becoming much more brittle or plants can even beginning to loose there leaves [4]. These are just some examples of plant malnutrition. However some evidence of malnutrition is much more difficult to spot such as the wrong patterns within the leaves and vain configuration or the flower buds are not opening. When a plant becomes malnourished it has begun its fight for survival. When a plant is fighting for survival it is very delicate and even the simplest imperfections will kill it. If one plant can be affected by an incorrect pH level than an entire crop culture can be affected in the same way.

## 2.6 Current Research

There are many automated and semi-automated greenhouse soil-less agriculture systems in use today. Many of these systems involve climate control systems, lighting systems and carbon dioxide enrichment systems. However many of these systems do not automatically test the pH of the nutrient enriched water solution before supplying it to the plants. This may be due to the lack of knowledge of what the wrong pH can do to a plant culture.

### 2.6.1 Floating Hydroponic Greenhouse

Cornell University has a CEA program. This program has been involved in greenhouse hydroponic systems for over 20 years. The program grows hydroponic lettuce. The original goal of this program was to develop systems to produce fresh, high-quality, pesticide free vegetables close to market. They implemented a greenhouse hydroponic system to grow vegetables year round with rapid production. They credit the success to their accurate greenhouse climate control system [25]. They use a greenhouse control system from QCOM Innovative Greenhouse Control. The control system has features of monitoring temperature, humidity, $CO_2$, irrigation and lighting. The irrigation control does monitor the pH of the nutrient solution. The pH of solution is maintained at 5.8 with a standard deviation of 0.2 [26]. The greenhouse is shown below in figure 14.

Figure 14: Cornell University Floating Hydroponic Greenhouse [25]

### 2.6.2 Lufa Farms Rooftop Greenhouse

In Montreal a company called Lufa Farms, founded by Mohamed Hage and Kurt Lynn, have turned an office rooftop into a 31,000 square foot greenhouse. This greenhouse uses hydroponic techniques to tomatoes, cucumber, peppers and other produce year-round. The Lufa Farms model is to sell directly to consumers through the use of a co-op. The greenhouse they have developed is much stronger than your ordinary greenhouse. It is built this way to withstand a great amount of snow and to deal with harsh weather conditions. The greenhouse also had to meet exact urban building codes. The greenhouse provides multiple growing climates for different vegetables to be cultivated in. it provides cool areas for some vegetables and warm for others. The farm also uses several different growing methods, which cater to the plants' needs. Also the farm is conserving resources by collecting rainwater from the roof and recirculating the water used for irrigating the plants. The heating system to the greenhouse is designed to absorb as much natural heat form the sun and the building it is standing on. The rest of the heat comes from high efficiency boilers. An automated system is being used to optimize the energy but not to control the environment or to automate any growing practices [27]. Figure 15 is an image of Lufa Farms rooftop greenhouse. However Lufa Farms is a very young company. As they expand an automated system will be implemented. Other urban farms in Montreal are creating partnerships with supermarkets to develop rooftop greenhouses on the tops of the supermarket buildings.

Figure 15: Lufa Farms Rooftop Greenhouse [28]

### 2.7.3 Summary

Cornell's program is an example of an automated growing system that is flourishing. The complete automated system by QCOM monitors everything involved in an automating greenhouse system. Lufa Farms is an example of how the industry is changing. Lufa Farms was founded in 2009 and their first prototype rooftop greenhouse was implemented in 2011. From the success shown by their website urban greenhouses will be the way of the future.

## 2.7 Existing Products

There are pH control systems on the market today. Some are integrated into complete environmental control systems as in the QCOM products. Others are stand-alone pH sensors. In this section we will discuss some stand-alone pH sensors as well as their capabilities and features.

### 2.7.1 The Bluelab Dosetronic Controller

The Bluelab Dosetronic Controller optimizes crop performance with consistent, accurate management of nutrient enriched water solution. The sensor provides continuous control of a desired level of nutrients and temperature of the solution. The sensor can also control the air temperature depending on what the user believes is more essential to the plants growth. Ideally the sensor is used within recirculating soil-less agriculture systems. The sensor provides continuous control over the conductivity and pH levels of a nutrient enriched solution by adding fertilizer and pH corrector into the mixing tank or main reservoir. The sensor can be purchased within two different packages. One is for commercial use and is sold for $2,900.00. The other is intended for hobby or in home use and is sold for $1,875.00. The sensor module has a digital interface which shows the actual conductivity, pH and temperature of the solution as well as the desired values for each [29]. In figure 16, the module is shown. On the left side is the actual readings of the solution and on the right are the desired values.

Figure 16: Bluelab Dosetronic Controller [29]

### 2.7.2 Hanna Instruments 5000

The HI 5000 is a stand-alone ready to use control system that allows for precise nutrient and acid control to a commercial grower as well as advanced home growers. The HI 5000 controls fertilizer injection and monitors pH automatically. The system can handle up to 5 stock tanks that can be used for multiple crops and customized blending. The fertilizer injection control is designed with a flow range from less than 1 gallon per minute (GPM) to 35GPM. The system includes a Blackstone pump that can handle full-strength acid. This keeps out the risk of dilution to the acidic solution. The system also includes flat tipped probes, which are highly resistant to clogging. Automated dosing features are available to allow the grower to optimize growth without spending time measuring, mixing and dosing the nutrient enriched reservoir or mixing tank. A visual flow meter has also been implemented for easy fertilizer and acidic solution flow adjustments. This system is for sale for $2,349.99 [30]. An image of the system is shown below in figure 17.

Figure 17: HI 5000 [30]

### 2.7.3 Summary

Both of these systems are very advanced and are packaged with the necessary pumps, plumbing, sensor modules and digital output interface. The digital interfaces are a great feature as they allow for the user to check the pH and conductivity of the solution at any time. However these systems do not have the capability to be integrated into greenhouse environmental systems for monitoring nutrient enriched solutions.

## 3.0 Proposed System

One of the main causes of malnourished plants is the wrong concentration of nutrients the plant is receiving, meaning the wrong pH levels of the nutrient solution. The automated pH monitoring system will accurately determine the pH levels of the nutrient enriched solution as well as maintain these levels within a range for optimum plant growth. The pH sensor will be integrated into a microcontroller. The microcontroller will act as the brain to the system and it will poll the sensors for information about the nutrient solution. From this information the microcontroller will either determine if the solution is within the optimum range of 5.5 – 7.5 on a pH scale. If the solution was not within the range the microcontroller will initiate the steps to correct the solutions pH. The microcontroller will monitor the nutrient solution by polling the sensors every 30 – 60 seconds. This will ensure the nutrient enriched solution will maintain a pH for optimum plant growth. A system level block diagram is shown below in figure 18.

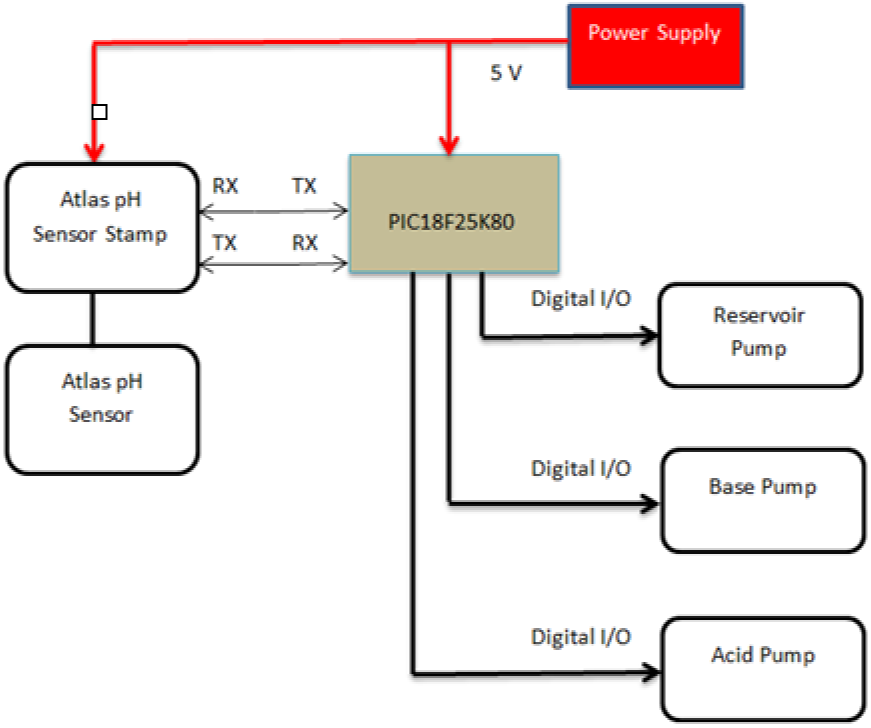


Figure 18: System Level Block Diagram

The goals of this project are to interface a pH sensor with the PIC, create a sensing module with 100% stability, create a sensing module that will accurately calibrate the pH sensor, creating a module that can accurately read the pH of a nutrient enriched solution, have the ability to add up to 100 nodes within a soil-less agriculture system, and have the ability to add and subtract a module with ease. The goal of interfacing the pH sensor with the PIC will include circuitry and wiring to allow the PIC and sensor to send and receive commands to and from one another. The system should be 100% stable to be able to monitor the pH of a nutrient enriched solution without any complications. Accurate calibration of the pH sensor will ensure that the pH sensor is operating correctly. Having the ability for the sensor to accurately measure the pH is crucial for the system to monitor and control the pH of the nutrient enriched solution. Having the ability to add up to 100 nodes or modules will allow parallel systems to grow a wide variety of plants. The ability to add and subtract the module with ease is essential for this system because it will allow for easy implementation and removal of the device.

## 4.0 pH Sensors

Controlled pH monitoring systems require sensors with fast response time, durability and accurate measurements. This chapter will discuss possible pH sensors that could be implemented with the pH monitoring system. Qualities that will be taken into account are data readings up to two decimal places, i.e. X.XX, easy implementation for interfacing with a breadboard and cost.

pH sensors measure hydrogen ion activity and produce a voltage. The sensor operates based on the principle that an electric potential develops when two liquids of different pH levels come into contact on opposite sides of a thin glass membrane. This was discovered by Max Cremer in 1906. The pH sensors today are composed of two main parts; a glass electrode known as the measurement electrode and the reference electrode. The tip of the measurement electrode is a thin glass membrane. The thin glass membrane is able to facilitate ion exchange. As the ions exchange they create a voltage that is measured by the measurement electrode. This voltage is converted into a corresponding pH level. The reference electrode's potential is kept constant. This is possible because the reference electrode's fill solution is kept at a pH of 7 [31].

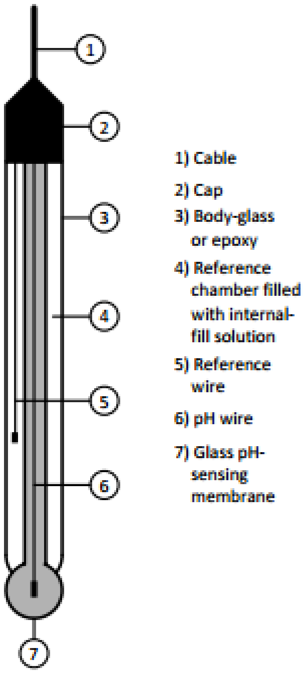


Figure 19: Measurement Electrode Diagram [31]

The pH sensor is a passive sensor, which means there is not a need for a voltage or current source. The sensor is classified as a bipolar sensor because the electrode's output can swing above and below the reference point [31]. The sensor produces a voltage output that is linearly dependent on the pH of the solution it is placed in.

## 4.1 Campbell Scientific CSIM11-L

This probe can measure pH of many ranges of solutions. It can be submerged in solution or inserted directly in tanks, pipeline and open channels. The probe cannot operate under any conditions over 30 pounds per square inch (PSI). The benefits of this probe include an internal amplifier to boost the signal which decreases signal interference. The porous junctions of this probe are made of Teflon which is less susceptible to clogging. Also due to the plunger-style of the pH glass electrodes, they are able to be mounted at any angle. The probe can measure full range of pH, withstand temperatures from 0° to 80°C and has the response time of 10 seconds with a 95% accuracy rating. Also the probe is internally powered by two 3V lithium batteries [32]. The price of the probe is not available on the Campbell Scientific website, but a quote can be obtained if necessary. An image of the sensor is shown below in figure 20.

Figure 20: Campbell scientific CSIM11-L [32]

## 4.2 Atlas Scientific Probe

The Atlas Scientific Probe is a silver-silver chloride probe that can measure the full range of pH, 0 – 14. Atlas Scientific ensures the probes are virtually unbreakable because they are enclosed in an epoxy making them very durable. It can operate from 1° to 99°C and has a response time of about 1 second. The sensor produces an analog output and operates between 2.5 – 5.5V. The probe measures pH to two decimal places, i.e. 5.51. The probe includes a BNC connector which allows for breadboard interfacing. The cost of this unit alone is $55.00 [33]. An image of this probe can be seen below in figure 21.

Figure 21: Atlas Scientific pH Probe [33]

## 4.3 Pasco pH Sensor

The pH sensor manufactured by Pasco measures the full range of 0 - 14 pH and can operate at temperatures between -4° to 80°C. This probe also measures pH to decimal places and is accurate to a standard deviation if 0.1 after calibration. The sensor can be purchased for $79.00 [34]. An image of the sensor can be seen below in figure 22.

Figure 22: Pasco pH Sensor [34]

## 4.4 Sensor Selection

The decision was made to purchase and implement the Atlas Scientific pH probe. This was due to its operation at low voltage using a DC power source as well as the relatively cheaper cost. In addition the sensor can interface easily in breadboard circuits and is able to deliver accurate pH readings to two decimal places. However this probe does not have an impeded amplifier for the output signal so an amplifier will need to be purchased as well.

# 5.0 Microcontrollers

A microcontroller is an integrated chip that is often involved in embedded systems. They include a central processing unit (CPU), Random access memory (RAM), read only memory (ROM), Input and output pins (I/O pins), and timers. This is very similar to a standard computer, but they are designed to execute a single specific task to control a single system. They are much smaller and much more simplified than a standard computer. These devices are meant to be self-contained and independent. Microcontrollers function as very small dedicated computers [35].

A microcontroller is an essential part of this system. The microcontroller will act as a brain to this system by polling the sensors for data on a timed clock schedule. Based on the data received by the microcontroller it will need to decide if the pH of the solution being tested is within the set optimal range of growing plants. If the pH of the nutrient enriched solution is not within the desired range the microcontroller will initiate the steps to bring the solution back into the optimal range for plant growth. The specific range can be set while programming the microcontroller and can be adjusted for any plant's specific needs. The micro controller will need to be able to support multiple sensors and be able to differentiate the signals from one sensor to another.

This chapter will discuss the microcontroller that was implemented for the automated pH monitoring system. The requirements for the microcontroller are to operate within the same voltage range as the Atlas pH sensor of 2.5- 5.5V, small current draw, multiple I/O ports, low cost and integrated network controller.

The PIC18F25K80 was selected due to its integrated CAN network, 24 I/O pins and 32KB of program memory. The PIC is an 8-bit microcontroller with 3,648 bytes of RAM. Although the automated pH monitoring system is not interfaced with CAN protocols it is a benefit to have the option to interface the sensor module with the network in the future. 24 I/O ports are more than needed for this application but it keeps the option of adding more sensors and more control outputs open for the future [36]. Although the PIC is much larger than needed for this specific application it leaves room for the automated pH monitoring system to grow.

The use of the integrated development environment MPLAB X in addition to the MPLAB C18 compiler was used to program the PIC. To compile and load the program to the chip the PICkit3 in circuit serial programmer was used.  The PICkit3 can also supply voltage over USB, which allowed for system trouble shooting without a DC power supply. The PIC was programmed to calibrate the pH sensor, to poll the sensor for data over the serial communication of RS232 and drive outputs depending on the data received by the sensor.

# 6.0 Hardware Design

Designing a circuit that will condition the sensors signal into a microcontroller can be difficult. There are a couple of steps to take before sending the signal into an A/D converter to be supplied to the microcontroller. First, the signal must be level shifted because the pH sensor produces a bipolar signal. Most applications such as the PIC operate on a single supply. The second step is due to the high impedance of the measurement electrode. A high input impedance amplifier is required.

To accomplish this, an amplifier off sets the pH sensor by about 500mV, the output of the amplifier is set up in a unity gain configuration. Also the output of this amplifier biases the reference electrode with the voltage of about 500mV at low impedance between 10MΩ - 1000MΩ. The measuring electrode produces a voltage that rides on top of the 500mV. Then the bipolar signal sent by the pH sensor is shifted to a unipolar signal to be used in single-supply systems.

Next, a second amplifier, we will call it the output op-amp, is also set up in a unity-gain configuration, which buffers the output of the pH sensor. A high input impedance within the same range as the other op-amp is used as a buffer between the pH sensor and microcontroller. For the Atlas Scientific pH probe the output from the second amplifier will need to further amplified. To do so gain resistors will need to be added to the second amplifier.

The amplified output, from the output op-amp, will then need to be supplied into an 8 bit A/D converter. This converts the analog signal to a digital signal that the PIC can understand. To send messages to the messages from the PIC to the pH sensor the signal will need to be sent into an 8 bit D/A converter. The signal will need to be shifted back into a bipolar signal for the pH sensor to understand.

A pH Stamp manufactured by Atlas Scientific is produced with the purpose of interfacing the Atlas Scientific pH Sensor with a microcontroller. It was purchased with a kit of pH solutions to calibrate the sensor. The pH Stamp allows has three I/O pins, two ground pins and a $V_{CC}$ pin. One of the I/O pins is bidirectional to communicate with the pH sensor. The other I/O pins are the receiving line (RX) from the PIC and the transmission line (TX) to the PIC [37]. An image of the pH circuitry is shown below in figure 23.

Figure 23: pH Circuit [37}

The PIC is interfaced with three LED's to show the initial steps in the control function of the system. The LED's are interfaced into the RB3, RB4 and RB5 I/O pins. The connections are made through 1KΩ resistors to supply a current of 5mA to the LEDs. The breadboard prototype is shown below in figure 24.

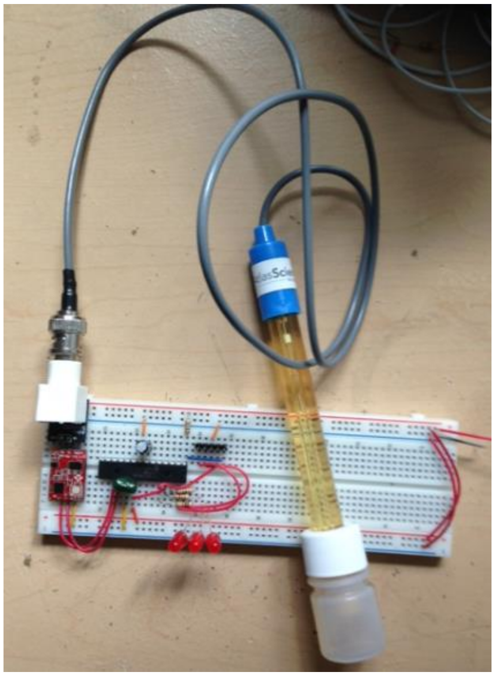


Figure 24: Breadboard Prototype

## 7.0 Programming

MPLAB X was used to write the program used to control the entire system. Before commands can be sent from the PIC to the pH circuit and vice versa, a communication protocol needs to be set and configured. The pH circuit supports RS232 serial communication protocol. The standard protocol used in asynchronous serial communication is RS232. Electrical characteristics, timing of signals, the meaning behind signals and pin out of connectors are defined by RS232 [38]. Below is a block diagram of the programs infrastructure in figure 25.

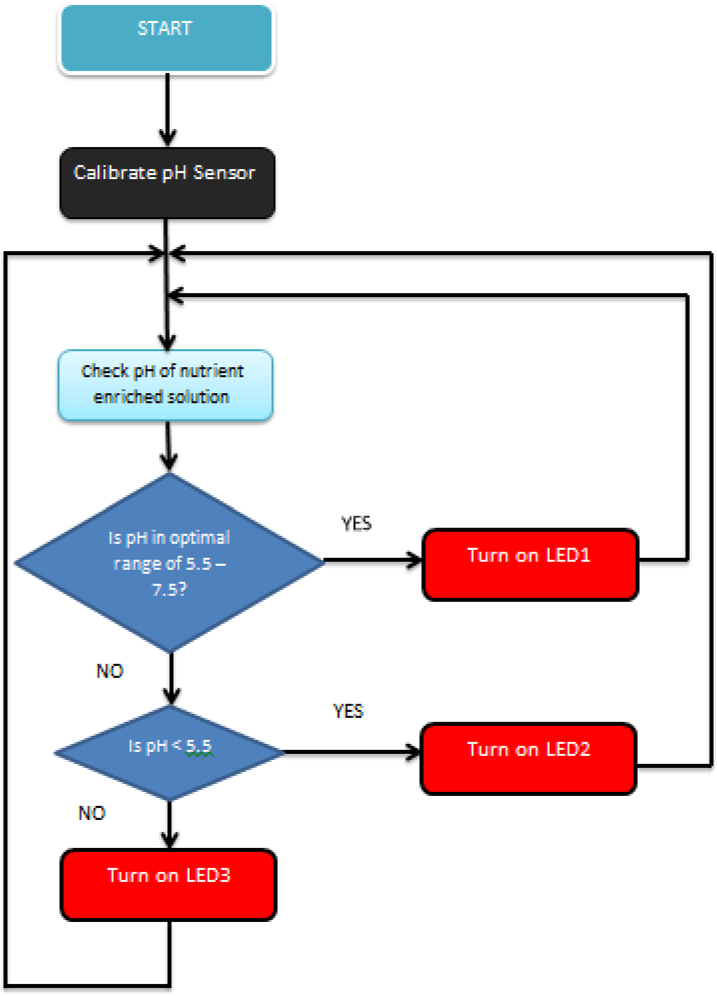


Figure 25: Program Block Diagram

The breakdown of the code is simple. The program will begin by calibrating the pH sensor. The calibration takes about 10 minutes but it is a one-time ordeal, however calibrations within year spans are recommended to ensure the sensor is still functioning properly. Once the calibration is finished the system level of the program will take over. This is the portion of the code that will be running at all times. Every thirty seconds the PIC will poll the sensor for the nutrient enriched solution’s pH. If the solution is in the optimal range LED1 will blink for two seconds. The program will wait 28 seconds before polling the sensor again. When the pH has fallen below the optimal range for the plant’s growth LED2 will blink for two seconds and if the pH has rose above the optimal range LED3 will blink for two seconds. The purposes of these LEDs are to show that the PIC can initiate the steps to start a power relay. A power relay can initiate a pump within basic or acidic solution tanks to bring the nutrient enriched solution reservoir back inside the optimal range for plant growth. The blinking of the LEDs exhibits the function of allowing the pump to run for a certain amount of time. The flow rate of the pump will be known, thus the amount of basic or acidic solution added to the reservoir tank can be set based on the reservoir tank size. Once the amount of solution is added the PIC will poll the sensor once again to restart the entire process. Unfortunately I was unable to get the program to compile. Without compiling the program, the program cannot be sent to the PIC. I was not able to see the systems full functionality. The code to the program can be seen in Appendix B.

## 8.0 Recommendations

Recommendations for future work to be done on the automated pH monitoring system are as follows: the implementation of an electrical conductivity (EC) sensor, the implantation of a nutrient solution temperature sensor, and to interface the system with a controlled area network. These recommendations are to enhance the system as a whole. These implementations would allow for a complete nutrient enriched solution monitoring system.

### 8.1 Electrical Conductivity Sensors

The addition of an EC sensor would greatly enhance the system. EC sensors measure the ability of material to conduct an electrical charge, which is measured in Siemens per meter. EC sensors gauge how a current can move in solutions. Like pH sensors, EC sensors are composed of two electrodes but unlike pH sensors, EC sensors are applied a voltage. The voltage reading is the resistance of the nutrient solution. Based on the distance between the electrodes the resistance can be calculated.

Ions are elements that have gained or lost an electron. Ionization is the process in which water breaks the ionic bond of certain compounds. These charged ions in water are able to act as electrical conductors and contribute to EC. It is important for growers to understand the relationship between EC and fertilizers. Fertilizers are salts that are added to water solutions that ionize into individual components. An EC reading will provide the fertilizer content of a solution as well as the salt content in a saturated solution. High EC values indicate the salts in the solution are high. EC readings cannot differentiate between different elements ionized in a water solution. They can however provide the sum of all the salt content [39]. While accurate pH values keep plants healthy, EC values can help to optimize the growth of plants and their fruits, may that be fruits or vegetables.

EC sensors would be a great addition to this system. The pH sensor would keep the solution within the optimum range to keep plants healthy and an EC sensor would allow plants to absorb essential fertile nutrients for maximum plant growth.

### 8.2 Solution Temperature Sensors

The addition of a temperature sensor to this system would be essential for the sustainability of the entire system. This is due to the direct relationship temperature has to the pH and EC of nutrient solutions [31]. Figure 24 below, shows the differences in pH for different temperatures of the solution.

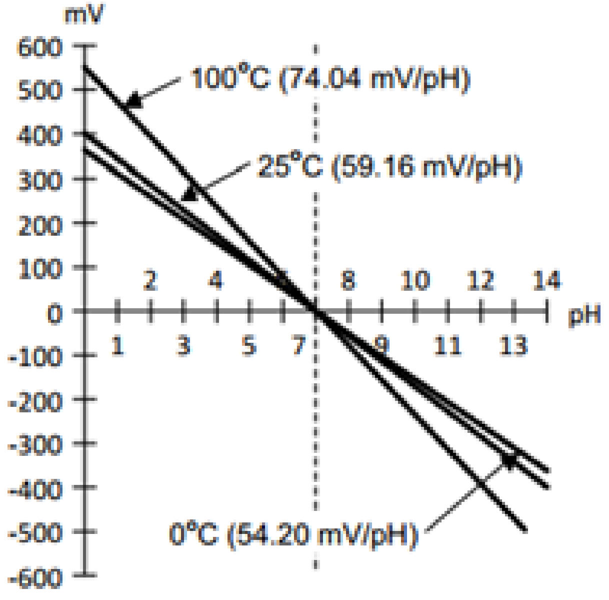


Figure 26: pH change as Solution Differs in temperature [31]

A temperature sensor added to this system would allow for more accurate pH and EC measurements. Therefore it would directly impact the sustainability of the entire system.

## 8.3 Communication Protocol

Interfacing the system with CAN communication protocols would allow for a master node to control this system. It would also allow the system to be split into a sensor node and a control node. This would allow for more sensors to be integrated into the system as well as more controls. CAN communication can be easily interfaced into the system due to the PIC. The PIC can easily be interfaced with CAN transceivers. These transceivers can interconnect different nodes over wired connections [40]. Cat5E Ethernet cables could be used to connect the transceivers to send data messages and transfer power.

## 8.4 Summary

The implementation of EC sensors, temperature sensors for water solutions and a communication protocol would greatly enhance the systems sustainability, functionality and interest in the market. EC sensors coupled with pH and temperature sensors would ensure the maximum plant nutrition and growth.

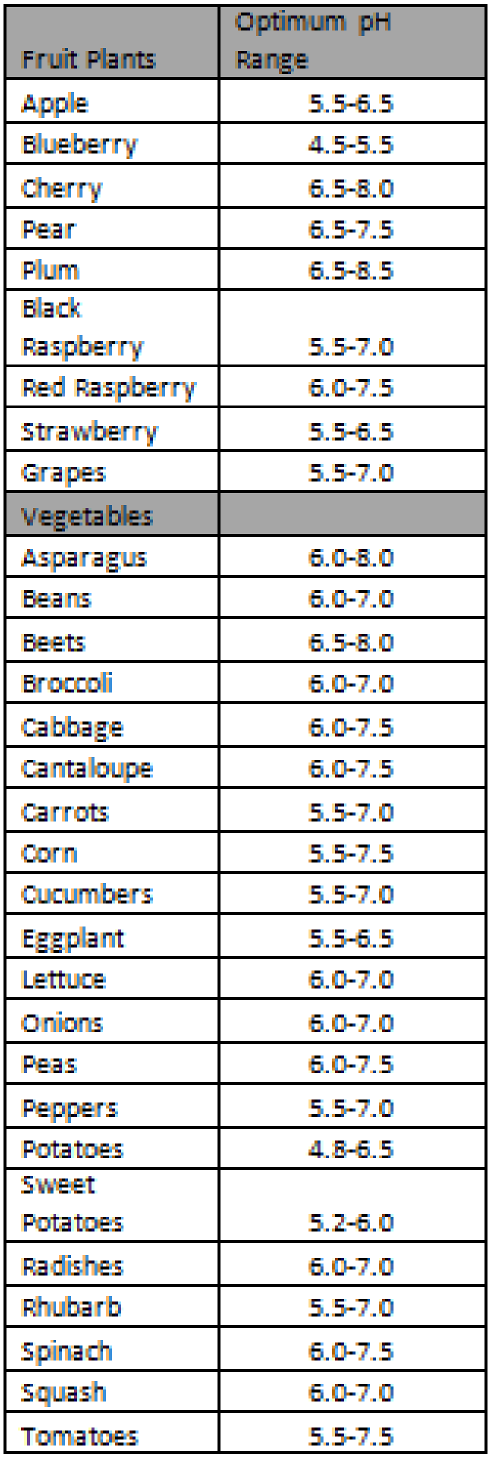
## 9.0 Conclusion

The goals of this project were to interface a pH sensor with the PIC, to create a sensing module with 100% stability, to create a sensing module that will accurately calibrate the pH sensor, to creating a module that can accurately read the pH of a nutrient enriched solution, to have the ability to add up to 100 nodes within a soil-less agriculture system, and to have the ability to add and subtract modules with ease. The goal of interfacing the pH sensor with the PIC was successful. The system was not able to be tested for stability because of the trouble with programing the PIC. Accurate calibration of the pH sensor was also unsuccessful due to the programming issues. The module was not able to accurately measure the pH of the nutrient enriched solution without a working program as well. However the ability to add up to 100 modules as well as the ability to add and subtract modules with ease was successful. This is due to the small size of the module.

As for the entire project, an extensive background research was completely to determine the area of monitoring pH of nutrient enriched solution for an automated system to be designed and created. The parts to create the module were successfully chosen and interfaced into a breadboard. However we were not able to test the systems functionality due to the lack of a working program to control the entire system. Given more time further trouble shooting would have been completed to the programming of the system until the prototype functioned properly.

# Appendices

## Appendix A: Optimal Ranges for a Variety of Fruits and Vegetables



| Fruit Plants | Optimum pH Range |
|---|---|
| Apple | 5.5-6.5 |
| Blueberry | 4.5-5.5 |
| Cherry | 6.5-8.0 |
| Pear | 6.5-7.5 |
| Plum | 6.5-8.5 |
| Black Raspberry | 5.5-7.0 |
| Red Raspberry | 6.0-7.5 |
| Strawberry | 5.5-6.5 |
| Grapes | 5.5-7.0 |
| Vegetables | |
| Asparagus | 6.0-8.0 |
| Beans | 6.0-7.0 |
| Beets | 6.5-8.0 |
| Broccoli | 6.0-7.0 |
| Cabbage | 6.0-7.5 |
| Cantaloupe | 6.0-7.5 |
| Carrots | 5.5-7.0 |
| Corn | 5.5-7.5 |
| Cucumbers | 5.5-7.0 |
| Eggplant | 5.5-6.5 |
| Lettuce | 6.0-7.0 |
| Onions | 6.0-7.0 |
| Peas | 6.0-7.5 |
| Peppers | 5.5-7.0 |
| Potatoes | 4.8-6.5 |
| Sweet Potatoes | 5.2-6.0 |
| Radishes | 6.0-7.0 |
| Rhubarb | 5.5-7.0 |
| Spinach | 6.0-7.5 |
| Squash | 6.0-7.0 |
| Tomatoes | 5.5-7.5 |

Table 1: Optimum pH Ranges of Different Fruits and Vegetables [41]

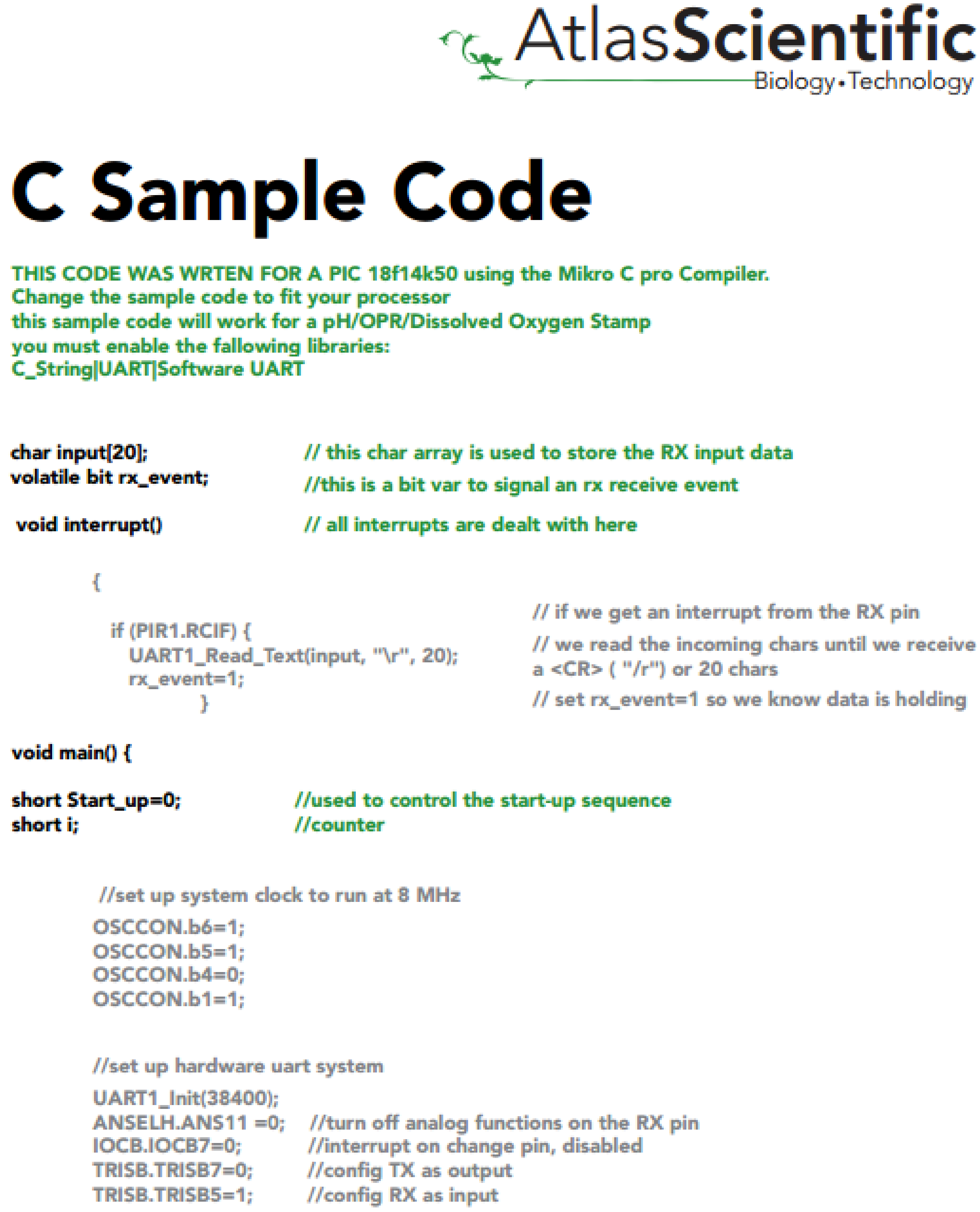
## Appendix B: Program Code for PIC

```
/*
 * File:   main.c
 * Author: Stephen Partridge
 * Debugger 1: Chris Walker
 * Debugger 2: Cori Nawn
 */
#include <stdio.h>
#include <stdlib.h>
#include <usart.h>
#include <math.h>
#include <p18f25k80.h>
#include <sw_uart.h>
#include <string.h>
#include <18f25k80_delay.h>
#include <18f25k80_adc.h>

char input[20];
volatile bit rx_event;
void interrupt() {
//this is a bit var to signal an rx receive event
// this char array is used to store the RX input data
// all interrupts are dealt with here
    if (PIR1.RC1IF) {
        UART1_Read_Text(input, "\r", 20);
        rx_event=1;
    }
}
int main(int argc, char argv) {
    short Start_up = 0; //used to control the start-up sequence
    short i; //counter
    int count;
     //set up system clock to run at 8 MHz
    OSCCON.b6=1;
    OSCCON.b5=1;
    OSCCON.b4=0;
    OSCCON.b1=1;

    //set up hardware uart system
    UART1_Init(38400);
    ANSELH.ANS11 =0; //turn off analog functions on the RX pin
    IOCB.IOCB7=0; //interrupt on change pin, disabled
    TRISB.TRISB7=0; //config TX as output
    TRISB.TRISB5=1; //config RX as input
    Soft_UART_Init(&PORTB, 4, 6, 38400, 0);

      //CONFIG UART INTERUPTERS
    INTCON.PEIE = 1; //peripheral interrupt enable
    PIE1.RC1IE = 1; //Receive char Interrupt Enable bit
```

```
PIR1.RC1IF = 0; //Receive char Interrupt flag- reset to 0
INTCON.GIE = 1; //global interrupt enable
rx_event=0; //initialize rx_evnet to = 0

while (count=1) {
    /*calibrate the device*/

 //calibrate w/ pH7
 usart_xmit_char( S );
 delay_ms(120000);//wait two minutes
 //calibrate w/ pH4
 usart_xmit_char( F );
 delay_ms(150000);//wait two and a half minutes
                  //too allow user to change solution
 //calibrate w/ pH10
 usart_xmit_char( T );
 delay_ms(150000)//Wait two and a half minutes
                 //allow user to change solution

 /* DONE CALIBRATION */

 //can reboot system to recalibrate if needed

 while (count=count) {//Program will run continuously

 usart_xmit_char( R )
 delay_ms(
 ***convert string to int

 if( pH > 5.5 && pH < 7.5 ) {//pH within optimal range
       for( i = 0; i < 100; i++ ){//LEDs blink for 2 seconds
            RB3 ^= 1;  //blink LED1
            delay_ms(20);//wait 20 ms before flashing again
            }
       }//end if
 else if( pH < 5.5){//pH has fallen below optimal range,
               //add basic solution to reservoir
       for(i = 0; i < 100; i++ ){
            RB4 ^= 1; //blink LED2
            delay_ms(20);//wait 20 ms before flashing again
            }
       }//end else if
 else {              //pH has rose above optimal range,
                     //add acidic solution to reservoir
       for(i = 0; i < 100; i++){
            RB5 ^= 1; //blink LED3
            delay_ms(20);//wait 20 ms before flashing again
            }
       }//end else
    delay_ms(28000); //wait a total of 30 seconds to check
                //solution again
```

```
    count = count + 1;//allows program to surpass
           //calibration protocol
}//end main
```

## Appendix C: PIC C Sample Code



AtlasScientific
Biology•Technology

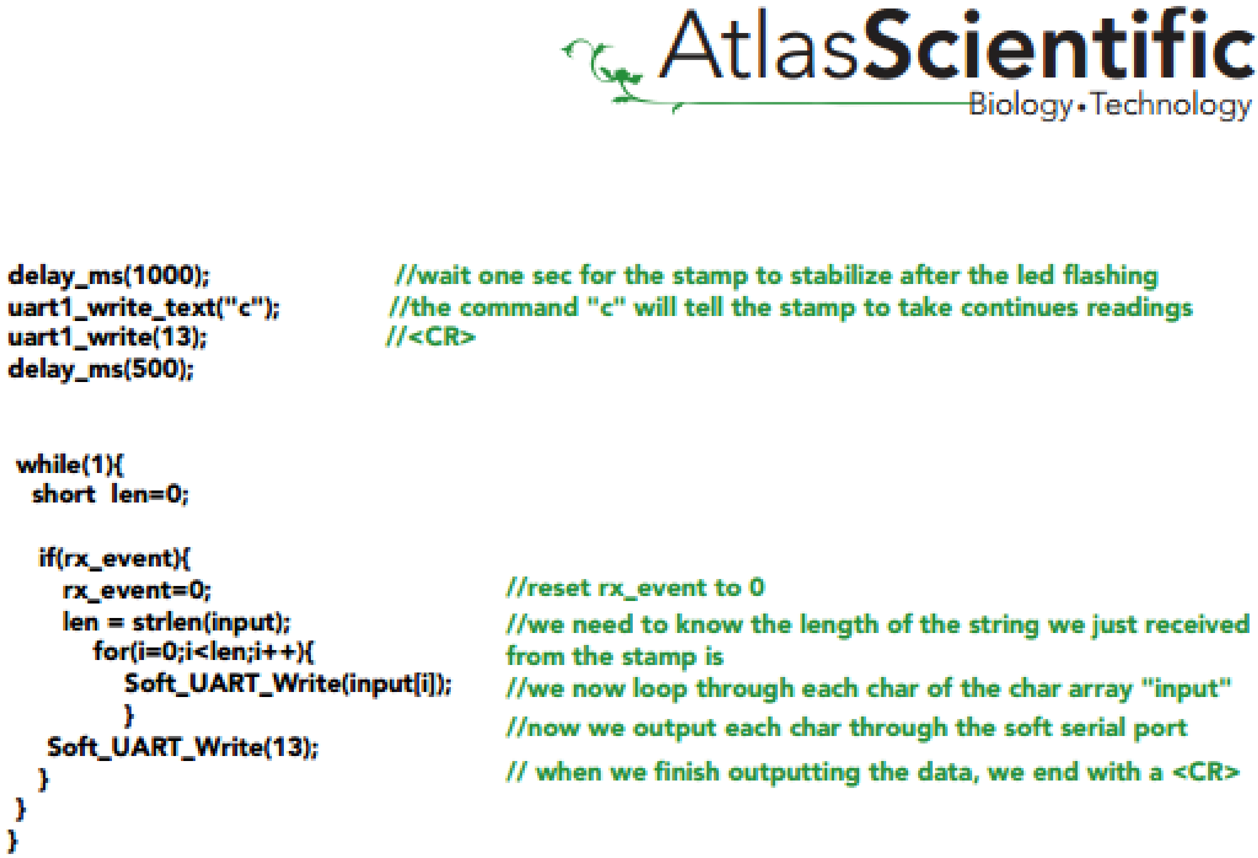
# C Sample Code

THIS CODE WAS WRTEN FOR A PIC 18f14k50 using the Mikro C pro Compiler.
Change the sample code to fit your processor
this sample code will work for a pH/OPR/Dissolved Oxygen Stamp
you must enable the fallowing libraries:
C_String|UART|Software UART

```
char input[20];                 // this char array is used to store the RX input data
volatile bit rx_event;          //this is a bit var to signal an rx receive event

 void interrupt()               // all interrupts are dealt with here

          {
                                            // if we get an interrupt from the RX pin
   if (PIR1.RCIF) {                         // we read the incoming chars until we receive
     UART1_Read_Text(input, "\r", 20);      a <CR> ( "/r") or 20 chars
     rx_event=1;                            // set rx_event=1 so we know data is holding
             }

void main() {

short Start_up=0;               //used to control the start-up sequence
short i;                        //counter


          //set up system clock to run at 8 MHz
          OSCCON.b6=1;
          OSCCON.b5=1;
          OSCCON.b4=0;
          OSCCON.b1=1;


          //set up hardware uart system
          UART1_Init(38400);
          ANSELH.ANS11 =0;    //turn off analog functions on the RX pin
          IOCB.IOCB7=0;       //interrupt on change pin, disabled
          TRISB.TRISB7=0;     //config TX as output
          TRISB.TRISB5=1;     //config RX as input
```

```
Soft_UART_Init(&PORTB, 4, 6, 38400, 0);        // Initialize Soft UART at 38400 bps
                    ^..........................port to be used
                                ^.....................RX pin (we are to going to use the RX function)
                                   ^.................TX pin (pin 11)
                                         ^............baud rate 38400
                                               ^........rs-232 data is NOT inverted


//CONFIG UART INTERUPTERS
INTCON.PEIE = 1;    //peripheral interrupt enable
PIE1.RCIE = 1;      //Receive char Interrupt Enable bit
PIR1.RCIF = 0;      //Receive char Interrupt flag- reset to 0
INTCON.GIE = 1;    //global interrupt enable
rx_event=0;        //initialize rx_evnet to = 0
```

```
delay_ms(1000);                     //wait one sec for the stamp to stabilize

if(Start_up==0){                    //when the program firsts starts it will
   for(I = 1; I<=3;i++){            //flash on / off the stamps led
    uart1_write_text("L0");         //"L0" = led's off
    uart1_write(13);                //<CR>
    delay_ms(1000);                 //wait one sec

    uart1_write_text("L1");         //"L1" = led's on
    uart1_write(13);                //<CR>
    delay_ms(1000);                 //wait one sec
  }
  Start_up = 1;                     //by setting Start_up to 1, we stop the leds from flashing on/off
 }
```



```
delay_ms(1000);                //wait one sec for the stamp to stabilize after the led flashing
uart1_write_text("c");         //the command "c" will tell the stamp to take continues readings
uart1_write(13);               //<CR>
delay_ms(500);


 while(1){
  short  len=0;

   if(rx_event){
      rx_event=0;                       //reset rx_event to 0
      len = strlen(input);              //we need to know the length of the string we just received
          for(i=0;i<len;i++){           from the stamp is
              Soft_UART_Write(input[i]);  //we now loop through each char of the char array "input"
              }                         //now we output each char through the soft serial port
    Soft_UART_Write(13);
   }                                    // when we finish outputting the data, we end with a <CR>
 }
}
```

Figure 27: Microcontroller Example Code [34]

# Appendix D: Parts List

| Parts List | |
|---|---|
| Parts | Cost |
| pH Sensor | $60.00 |
| PH Circuit | $28.00 |
| PIC18F25K80 | $3.38 |
| BCN breadboard connector | $6.50 |
| | |
| Total | $97.88 |

Table 2: Parts list

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