# Smart Buoy

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***Abstract* — Throughout this paper you will read about the data buoy system we have designed and created in the past two semester of senior design. The readings will introduce some of the specifications and requirements that went into designing, as well as the hardware and experimenting that was used for the physical system itself. The smart buoy was designed to outdo any other buoy system used for recreational use today. The functionality is quality for small scale use and can be ever expanded.**

***Index Terms* — Mobile applications, photonics, solar energy, temperature measurement, wireless communication.**

## I. Introduction

Living in Florida, we are always within a short distance to some body of water. Rivers and waterways are part of most Floridians everyday life. Water and air conditions have been monitored for centuries through the uses of mechanical and electrical devices. With technological advancements, measurements in these areas are improving and becoming much simpler of a task for most people. From television to car radios, and now even cell phone apps, it only takes seconds to determine what the weather is like outside. On the other hand, there are few devices out today that can give all the features of local water and air, like the data buoy system we have designed and created. Intended for anyone who has a passion for the water or possibly a job consisting of boating, this buoy makes checking conditions very simple.

The purpose of this design project is to integrate several electronic components and devices to implement a fully functioning air and water condition data buoy. Throughout this paper we will discuss a variety of different elements and components that it has taken to produce our completed design.

One of our main goals that we wish to achieve is to deliver a completely functioning buoy system that will be able to monitor and record valuable data used by the average water sports enthusiast and in-the-field commercial users. The objective of this project is to implement a microcontroller that monitors various sensors simultaneously to produce a buoy system that allows any person to simply check the water conditions of the surrounding area. This will be a valuable device with intentions to be focused towards the recreational fishing or diving enthusiast. With that in mind, we aim to make the overall cost low while keeping the functionality high. The final objective is to incorporate several electronic sensors, parts and elements to produce a product that can be attainable by the average middle to lower class individual.

The buoy will be intended for the use of checking water salinity, monitoring as well as recording water temperature, air temperature, and wind speed. With these multiple sensors sampling the surrounding water and air conditions periodically, the buoy system will allow any person to electronically check and monitor these sources at any time. The simplicity of this system will be through the wireless communication interfaced to an application on the user's phone.

The specifications were narrowed down by the members of the design group where the buoy itself is made of a durable plastic material housing which keeps the buoy afloat on the water in which will be best for measuring the data needed. The housing also acts as a host to a microcontroller, as well as several sensors, switches and LED's that have been implemented into the design.

A microcontroller was first implemented into the design to act as the "brain" of the buoy system. The microcontroller analyzes, measures and records data through the various sensors integrated in the buoy. The microcontroller is being powered by a small portable battery. The battery is capable of charging throughout the daytime with the use of a solar panel attached to the housing. This will help the battery stay charged so that the user does not have to keep removing the buoy from the water and charging or replacing the battery.

The solar panel that will be used will charge the small portable Lithium Polymer battery during daytime hours allowing enough power if the buoy is to be used during night time hours while not charging. The panel has been attached to the top portion of the buoy for maximum sunlight during peak hours of the day. The panel is waterproof in a chance of harsh weather conditions such as rain and storms. This also helps in the case that there is always a chance the waves come over the buoy if the surrounding water is rough enough.

The water salinity testing will be performed through the use of a laser, photodetector and photonics. The circuit itself will consist of a laser diode, a mirror, and a photo detector. The salinity detection feature will be added to the lower portion of the buoy where the beam of the laser can shine through the water it will be sampling. From the implemented circuit we will be able to detect if the surrounding water has salt content. Temperature sensors will be integrated into the system to monitor the air and water temperatures. The water temperature sensor is waterproof and integrated into the lower portion of the buoy suitable for monitoring accurate readings of data. The air temperature sensor is mounted on the top portion of the buoy which will make monitoring the temperature of the air relatively easy. This sensor is waterproof as well in case of bad weather or rough waves coming over the buoy. The wind speed feature has been designed and integrated through the use of an anemometer which will monitor the force and velocity of the wind. This feature will be integrated onto the top of the buoy system clear of any other parts of the buoy or surrounding structures. The integration of all these features is a result of a fully functioning buoy system that provides valuable data interfaced wirelessly to the application on the user's smart phone.

## II. MOTIVATION

Having a design group consisting of two electrical engineers, one computer engineer, and one photonics engineer, our motivation was to come up with an idea that will test our understanding and incorporate the knowledge acquired throughout our educational careers, combined with finding something that is associated with all of our interests. The thought of designing the fully functioning water and air condition data buoy is more difficult and complex than it seems to be. To simplify our outlook on the buoy design project we separated the concept into four main aspects of this particular project:

- Physical Aspect
- Electronics Aspect
- Photonics Aspect
- Programming Aspect

The physical aspect will be the buoy housing design and the how the components are going to be integrated in the system making it space efficient for its portable design. After doing some research, the route of going with the 3D printed model of a buoy housing would have raised the cost and extended the time of production. With that in mind, we decided to find a product that could be purchased from a local store. This is where we found the TruFlo oil dispense container. It is very cost efficient, small in size, light weight, durable, and has a large compartment to house our components inside secure and dry.

The electronics aspect is what we figured would determine the overall capabilities and features that would be incorporated into the buoy system. To begin, we chose the microcontroller best suited for our intensions. After coming to an agreement on the Atmel ATmega328, we needed to draw out how the other electronics components and sensors were going to be implemented off of it. Being that the microcontroller is essentially our "brain" of the system, we must design and build from there. Once the components were implemented with the microcontroller, the Micro Controller Unit (MCU) was obtained. The Atmel ATmega is a chip used in the Arduino UNO that has multiple input and output pins to connect to different electronic input and output components, creating a bridge of communication between itself and the other components, which will later be embedded into the design.

To supply power to the MCU, we have included a small rechargeable Lithium Polymer Battery. With this battery we included a solar panel keep the battery charged during lowlight situations. The solar panel is connected to the LiPo battery through a charging module. This module allows the battery to be charged by the solar panel while discharging to the load.

Looking into the photonics aspect of the project, the views are similar to the electronics aspect. While there are options available commercially for buoys that detect many of the same data our buoy system records, it seems there was no current industry standard for measuring salinity in the water. In the hopes of creating a new useful module and an overall useful device we added a photonics sensor to measure the salt content. We chose a laser diode preferred for use in the visible spectrum for ease of alignment and correction. The mirror was decided to be round and small to fit the design of the sensor. The whole system has been aligned and configured to be able to tell if there is or is not salt detected in the surrounding water.

As for the programming aspect, we have a determined computer engineer that has spent many hours working with the challenges of this project. The electrical and photonics engineering members, though not best suited for this task, have also taken several classes making them able to handle simple and less complex coding and implementation. The reason for programming being such a major portion of the project is because without some sort of code, the microcontroller will have no commands of what to do. The microcontroller has needed intensive written code being that the MCU needs to handle converting digital and analog signals. The MCU needs to be able to know when the sensors are communicating as well as be able to translate the input and output voltages into understandable values such as Volts to degrees Fahrenheit for the temperature sensors. Furthermore, when we look into the wireless interface between the actual device and the users smart phone, this requires some programming as well.

With all four aspects taken into consideration, combining them creates our overall vision of how this design project was created. The motivation gives us a general idea of how the design started, what needed to be incorporated, and what our overall achievement were.

## III. Requirements

We have decided that with the many possibilities able to be achieved, we have set some requirements that set our buoy a little better than the rest. From wind speed to water salinity, this device will be valuable to any water sports enthusiast. The 5 categories the requirements of this project fell into were:

- Durability
- User Friendly
- Electronically Advanced
- Functionality
- Portability

The design we have implemented and built has created a possibility for the average recreational water sports enthusiast to own a cost efficient water and air condition buoy system that is able to be transported and used wherever needed. With the overall price being a fraction of the cost compared to commercial systems and other competitors, the average person will be able to utilize this technology.

This project has been a production of an affordable and accurate data buoy that incorporates several different sensors and technology, to produce and easy-to-use and durable data buoy system. The project also entails the buoy system monitors and records data that can be valuable for commercial users as well as recreational users. The buoy will provide sufficient data for knowledge of the local air and sea conditions. After doing some research, we became more familiar with the implementations of other data buoy systems that have been designed and are being used today. With the information collected, we found that most data buoys used today are large, expensive, or aimed mainly toward commercial side of use. With that in mind our data buoy will resolve all of the aforementioned areas.

Multitude of features: from air and water temperatures to salinity detection, this buoy will have the key features to anyone who needs to check water and air conditions. The buoy will consist of two temperature sensors. The first of which will be used for measuring the surrounding water temperatures just below the surface. The second will be used for measuring the air temperature above the buoy and nearby. Another sensor that will be used is the wind speed sensor. This will be mounted to the top of the buoy as well and monitor the speed of the wind. Last but not least, we have added the salinity detection. Through which, the local fisherman can determine what type of water is in the lake or river they are in, which lets them know what kind of fish they will be catching. We have determined that these features can be useful for commercial use as well. For example, if a sea surveyor is in the field and needs to take water samples, he or she could simply set the buoy in the water and collect the data for looking back on later while examining the samples.

Transportable: The buoy will be designed with a dimension small enough that it is portable and can be transported wherever it may be needed. If the user needs to bring it along to different lakes or rivers, then there will be no hassle. The buoy housing itself will only need to be large enough to fit all the needed sensors and components, thus making the overall size small and compact.

Durable: Being that the buoy will spend most of its lifetime in or around water, we have designed it with durability in mind to minimize the chance of any damage that can be caused. The buoy housing must be able to withstand vigorous waves when the water is rough. This entails having a suitable and very waterproofed system inside and out. Also if the buoy is around any structures, the housing must be strong and solid, making it capable if any contact occurs.

Long Battery Life: The battery we are currently researching and electing to use will have a long battery life and slow discharge rate due to the low power and sleep modes in the microcontroller. During use the microcontroller will be recording data at certain period of time, making it be able to use the low power mode in between samples. Wireless transmission can be power consuming, so we decided that only when the user opens the application and selects which sensor to collect data from, the microcontroller will understand and transmit the recorded data. The largest contribution to the low power system will be that we will have a solar panel implemented into the system to keep the battery charged.

Affordable: Unlike most data buoy systems being used today, this design will be cost efficient and take minimal funding during ownership. Being that the buoy will be personally owned and operated, there will be no costs tied to the device. For our goal of being able to design this system for less than a few hundred dollars, this can be a valuable product for its price.

After looking into a few of the major benefits of our data buoy system, we found that in comparison to many data buoys today, this device is an improvement towards recreational and personal use as well as in-the-field jobs. Many of the devices seen today are massive, excessively costing, and non-ideal for anyone other than a commercial company or organization. We made it our goal to design a more down to earth data buoy for the average person to use.

## IV. Hardware and Design

### A. Power System

As mentioned before, the buoy is solar powered. Therefore, a solar panel is fixed on top of the buoy housing to provide the necessary solar energy to power our system. Also, given the mobile nature of our project, we have decided to use a rechargeable battery as our power source. The solar panel is connected to a battery charger which utilizes the solar energy to charge the LiPo battery. The battery's output voltage is fed back to the battery charger and it goes through a boost converter which connects to the load.

Our choice for solar panel is a 6V, 2W output solar panel bought from Adafruit. This solar panel is durable and lightweight, scratch resistant, perfect to mount on top of our buoy housing and most importantly waterproof.

For our battery we chose a lithium polymer battery. This battery technology has a very low self-discharge rate and it lasts for approximately 400 cycles of charge/discharge. Plus, it does not require any maintenance. The nominal voltage of this battery is 3.7V and it has a capacity of 1200mAh.

This battery charger is based on the MCP73871 microchip. It is capable of monitoring the battery's temperature, which is very important because the interior of the buoy housing can get really hot after begin exposed to the sun for a long period of time. It comes equipped with three indicator LEDs, one for power that shows if the solar panel is providing power or not, one for the battery's charging status that indicates whether or not the battery is currently charging, and one that indicates when the battery is fully charged.

The boost converter is necessary because our LiPo battery has an output voltage of 3.7V and our microcontroller requires 5V. What it does is that takes the voltage from the battery and it boosts it up 5V.

### B. Data Sensors

The DS18B20 has been determined the most suitable temperature sensor that can be used in our project. The decision fell on the digital architecture and the option of getting it in water proof form. With its programmable digital architecture, it will handle measuring temperature with the needed amount of precision and accuracy. This sensor will be used for both, the water and air temperatures. Since the DS18B20 has the option to come in a water proof form, it will handle the wet environment of the data buoy system. With this sensor integrated into our system we will have the capabilities of water and air temperature sensing.

After looking deep into many wind speed sensors and doing extensive research, we decided on the most suitable and accurate component for our data buoy system. We determined that we will be implementing, as well as doing further research, on the Adafruit Analog Wind Speed Sensor. After comparing and contrasting with the other devices available, we believe this one is the best applicant for our system.

The idea of salinity detection revolves around measuring salinity using the change in refractive index in the sample as compared to a completely distilled water sample. This method uses a laser diode that is coupled into a fiber optic cable, which in turn carries the light into a distilled water sample, passing through a clear divider into the sample and back into a fiber array. This fiber array would show where the beam has moved to on a CCD camera which would allow detection of salinity when comparing to the position of the beam when the sample has no salt. The laser diode used in this system will have a certain emissions wavelength in the visible spectrum which will be sent through a multimode fiber to a closed compartment underneath the buoy that will allow water to flow through to be tested. The chosen wavelength for this sensor is approximately 650 nanometers which is in the red light region of the visible spectrum. The light will emit through distilled water first, pass through a clear wall into the sample, reflect through a prism and back through the sample before entering an array of fibers which will carry the light back to a CCD camera that the array is focused onto. The CCD camera will detect the location of the spots for the given sample and by creating a database from no salt content to high salinity content we will be able to determine the salinity of the sample.

### C. Microcontroller

We decided that the ATmega328P microcontroller might be the best suited for our design given that it fulfills all of our requirements and we have plenty of experience working with it on an Arduino UNO board. Most of our sensors are compatible with the Arduino UNO board, which is equipped with this microcontroller, and a wide variety of resources are available. This will help us a lot with the programming of the microcontroller to read data recordings from our different sensors implemented in the data buoy.

### D. Wireless Communication

We decided that we will be using Bluetooth to communicate with the user. Once we made that decision we also determined that the HC-06 Wireless Bluetooth Serial RF Transceiver was the best suited module for our data buoy system. Although the other two modules researched had slightly better range of use, there were many other features that made or decision more clearly. We found that price was more important of a factor than the range of use. Also, the HC-06 has a very simple connection and setup procedure making implementation quick and easy. The last reason we chose to use the HC-06 is because its size is very small and even with its own built in antennae.

## V. Specifications

From the start of this design project we have been looking for ways to minimize size and cost, while maximizing functionality and efficiency. Since we needed a footprint to start off with, we set some specifications for the system and each of the components. The following few paragraphs will cover the specifications that were set and our successes of meeting them.

To begin, we looked into all the components that were needed to form the buoy system. Based on that we were able to determine the size of the buoy as well as the battery to power it. As for the electrical components themselves, we have decided that we wanted to make our system solar powered. Also, for the functionality we set some specifications for precision and accuracy range. As for the temperature sensors, we set the accuracy range to be up to 150° F and the precision to be within a half of a degree. For the wind speed we made the range of velocity up to 60 mph and the precision to be within 0.5 mph. The salinity sensor we set our spec to be able to determine if there is the presence or absence of salt in the surrounding water.

Accounting for the sensors, battery, solar panel, PCB, and charging module, we determined the size of our buoy would be under 20Hx20Lx20W. From everything considered we also set an overall cost specification to meet. The total cost of our buoy was to stay under $100 per group member or $400 for the overall team.

In the end we have found that we were able to meet all of our specifications. Our size is just under the original and our sensor specs were all within their ranges. With the total cost to date collected for a single buoy built we were able to stay under our total budget by almost $150.

## VI. Experimental Studies

To begin our testing of the temperature sensors, we used instruments that could accurately measure the air or water temperature so that we can compare the two readings and determine if our component is working properly. We began by finding a thermostat in a room where the inside temperature was clearly visible. We then used our DS18B20 digital temperature sensor to record the temperature in the same room. For the water temperature feature we did similar testing. We began by taking a cup of water and microwaving it for a short period of time. Next we used a digital thermometer to record the water's temperature.

The first step in testing for the salinity detection was to align the beam onto the sensor at the proper angle into the sample to make sure the beam divergence of the salinity change would not cause the beam to deflect off of the sensor. Once the beam was aligned the next step was to establish a baseline for the water with no salt. The next step was to set a salt level to test for in each sample which had to be carefully controlled. A table will be created and added to show the amount of water used and the corresponding salt added for each data set obtained to establish our baselines for the device in use. These tests were repeatedly several times to determine the consistency of the equipment and determine if changes in environment affect the results as well.

In order to test our chosen microcontroller, Atmel's ATmega328P, we decided to use an Arduino UNO board. The Arduino UNO board is equipped with our chosen microcontroller and because of that it is perfect for us to use to for testing purposes. To verify that our microcontroller is capable of being the "brain" of our design, we used it to test our chosen sensors.

## VII. Conclusion

Throughout our design project we have had our advantages and disadvantages, ran into more issues than we initially expected, and changed design multiple times. With that being said, our overall design is what we had hoped to achieve and we already have more ideas for future development being discussed.

During our experiments we learned a lot about analysis and design, troubleshooting, working with multiple electronic measurement tools, as well as professionalism, organization, teamwork, and leadership.

The experimental portion of the data buoy consisted of researching, designing, prototyping, testing, and building in that order. While researching all of our components to the buoy system we made sure to keep our specs and requirements in mind. We wanted simplistic design while still having multiple functions. Research went hand-in-hand with design due to making it the most efficient way of working together as a team. When prototyping we made sure to collect all the components and put everything together on a single breadboard. Once we found that this was successful, we were able to make our Printed Circuit Board. The testing of the SMART buoy system was relatively easy due to our bread boarding being so successful. Last was the fun part and we got to build the overall data buoy and put everything together in the housing. We took full advantage of using the Senior Design lab on campus due to having everything needed on hand.

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