Farming in the Climate Change Era

Project Document

ECE 443

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1 - Overview

1.1 - Executive Summary

The goal of the Farming in the Climate Change Era project is to create a field deployable system to monitor the volume of water that is applied to a field. Gerrad Jones, an environmental engineer and chemist at Oregon State University, has tasked our team to develop this system of water management for the Quechan Indian Tribe in Southern California. The tribe is located in Imperial Valley, near the US/Mexico border, in one of the most agriculturally productive areas in the world; however, this region is naturally very dry and must be irrigated year-round. The system will measure and record instantaneous flow data, and then send that data to a remote server where it can be displayed and viewed by water managers to track water application in real time.

The Quechen people need to be able to more effectively utilize the scarce water resources that they have available to them. Imperial Valley receives only 3” of rainfall per year, and the state of California is now requiring water application data that would require the tribe to purchase expensive systems to record the data. There are expensive alternatives available, but the tribe does not have the budget for these options. Ultimately, our system will be able to take pressure off of the tribe and allow its 2000 members to more effectively and efficiently produce crops and sustain their livelihood.

The project will go through several phases until completion. First is the research, analysis and design phase. The impacts of our project on society, the environment, and the tribe are all considered. Analysis of the problem and how to most efficiently and effectively solve it are all important stages of the design process. In addition, the requirements of our project are defined in a way that the team can meet each of them, but they also satisfy the project needs. The system will measure water flow through irrigation gates, transmit, and report that data. This will be done using Maxwell’s equation for water flow, and the LORA communication method. In addition, it will have a solar power system, and also a reserve battery. It will also be designed ruggedly so that it can survive without maintenance for extended periods of time outdoors. Then the block diagram and interface definitions are created, and the project is designed and built block by block. Finally, the assembly and testing of the system as a whole is done to verify each of the requirements is satisfied.

Currently the system design is being finalized and block implementations will begin soon.

1.2 - Team Communication Protocols and Standards

1.2.1 - Contact Information

Team Member	Phone Number	Email
Eric van Klaveren	503 - 930 - 1886	vanklave@oregonstate.edu
Nicholas Ung	971 - 412 - 0077	ungni@oregonstate.edu
Liuqiao Song	541-908-2562	songliu@oregonstate.edu
Alexander Eamons	971-300-8644	eamonsa@oregonstate.edu

1.2.2 - Team Standards

Subject	Objective	Standard
Deliverables	On time achievement of tasks	Each deliverable/task that the team has must be completed on time. This includes individual blocks and team assignments.
Organization	One place for all project information and documentation	All of the project information and documentation will be stored on a shared google drive.
Quality	Satisfy all class requirements and project partner requirements	All of the work that each team member completes must be professional quality. It should be able to earn an A in the class and approval from the project partner.
Communication	Single method of communication for all of team/project related information	A team discord server will be used, and different channels will be created to organize different parts of the project.
Inclusivity	Every team member will have an equal voice	All aspects of teamwork and communication will be inclusive to each member. Decisions will be made via discussion, and open

		mindedness will be required and constructive criticism will be respectful and taken into account.
Finances	Method to approve transactions and purchases	All transaction and purchase requests must be approved by the team in advance of the purchase.
Absences	To have no unexcused absence or confusion on attendance	All team members must be present at each meeting. Absences must be relayed to the group 6 hours in advance.

1.2.3 - Project Partner Information

Gerrad Jones - gerrad.jones@oregonstate.edu

- Wildlife Biologist, Environmental Engineer, and Environmental Chemist

Communication

- Email
- Meetings Friday afternoon
- Always open to conversation
- Interested in updates/progress of the project

Role

- Source for clarification on requirements
- Connection to the tribe and tribe technician
- Guidance for direction on the project
- Not a source for technical EE information or sensor troubleshooting

Expectations

- Final Product will accurately measure water through gates (See requirements)
- Project can be delivered to Quechan Tribe
- Project is adaptable to many water gates, one size fits all
- Project does not depend on a power source

1.3 - Gap Analysis

The purpose of this project is to explore the design of a water monitoring system to be implemented in rural farming applications. While technology is slowly making its way into all different livelihoods, farming is a very traditional and relatively slow developing field. In a business that is often passed down from generation to generation, there is a set way of doing things, and advancement is less likely to occur. This is especially true when trying to replace tried and true methods with newly advanced technologies. While these traditional methods have their merit, there is much left to be desired from an efficiency standpoint. Without technology, water consumption measurements are left up to subjectivity, such as feeling the dampness of the soil.

Combining the SmartRock (OPEnSLab-OSU) system with a more advanced water monitoring solution will allow farmers to more accurately measure water consumption, and adjust watering habits for optimal crop health. Utilizing this combination of technologies can have great economic, as well as environmental impacts. Having this quantifiable view of water consumption will allow for farmers to correlate water consumption and crop health to determine the appropriate watering levels. This will eliminate over watering, which reduces effects of land erosion, as well as water waste. An additional benefit that can be seen from this is increased crop yield. This comes from the ability to monitor trends based on water consumption data, and viewing the general health of crops.

1.4 - Timeline

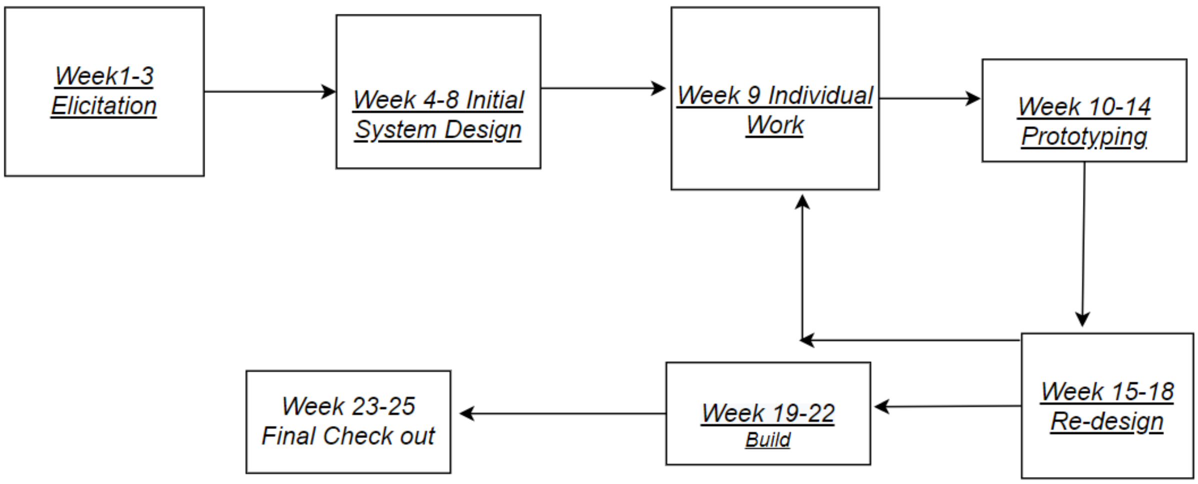
TIME	Goal	Plan	Completion Detail
Week 1-3	Elicitation	The first phase of the project is working with the project partner to determine exactly what it is that they want, and how much of that is feasible for us to deliver. We will communicate with each other until we have come to an agreement on what the system will be able to do.	From week 1 to week 3, we meet our mentors and as a group to talk about the project. Each of us has a basic understanding for the project.
Week 4-8	Initial System Design	The second phase will be the initial design phase where a rough overview of what the system is going to be and how it will perform all that functionality that we need to deliver will be made up. After which point the system will be split up into a block diagram made up of individual distinct sections.	We are familiar with the team members to understand the project background and core technical principles, and learn one by one according to the design sequence, design the basic plan and answer questions

Week 9	Individual Work	Next the phase will be delegating within the team who will work on each section of the project. After which point each group member will begin working on the specifics of the design of each of their delegated sections. By the end of which each member should be able to provide the code or schematic necessary for the construction of each of their delegated sections, and have ordered the parts needed to build at least a prototype.	

Week 10-14	Prototyping	After all of the individual sections have been completed they will then have prototypes built and tested individually to make sure that each individual section is able to perform its required function. To do this we will need to have ordered the parts needed to build each of the sections. Then each of these individual prototypes will be combined with the others until a mock system is built and functional.	

Week 15-18	Re-design	After the prototype is built there will be potential improvements that are made apparent. Whether it’s the project partner who isn’t satisfied with the current design or a member of the group there will be some changes that need to be made. It’s more than likely that each section will undergo some change from the initial prototype other than the improvement in professionalism that comes from not being a prototype. The revisions will need to be logged for reference.	
Week 19-22	Build	After the system has been tested and improved to the point where it is able to perform all the tasks that it was set out to perform, a final system will be built	
Week 23-25	Final Check Out	The final system will be built and tested to be sure all parameters are met. Then the documentation will be	

		finalized and the presentation will be completed.	



1.5 - References and File Links

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1.6 - Revision Table

Date	Changes
10/20	Initial Release
11/3	Eric van Klaveren: Updated Executive Summary
11/5	Eric van Klaveren: Added Contact info, standards table, and partner information
11/12	Alexander Eamons: Redid references and file links to match IEEE standard, and added in-text citations
11/17	Eric van Klaveren: More updates from feedback
12/1	Eric van Klaveren: Updated Executive Summary

2 - Requirements Impacts and Risks

2.1 - Requirements

Number	Engineering Requirement	Verification
1	The system will operate normally for one month without charging.	Method: Analysis 1. Detach the positive 5V output from the solar power supply from the system load. 2. Using a Digital Multimeter to measure amperage, attach the positive probe to the positive 5V terminal. 3. Now taking the negative probe of the DMM, attach it to the positive 5V input to the load. 4. Taking recording of normal operation, observe the maximum measured load current. 5. Now detach the 5V solar cell input to the battery charger. 6. Attach the positive lead of the DMM to the 5V output of the solar cell. 7. Attach the negative lead of the DMM to the 5V input of the battery charger. 8. Similar to step 4, observe the input current under normal operation. 9. Compare the solar input and load currents, and ensure that the charge rate exceeds or equals the discharge rate of the battery.
2	The device will store 6 months of raw pressure data without filling up to 80 percent of the total storage space	Method: Analysis 1. Power on the field system 2. Let the system run for 6 hours 3. Power off the field system 4. Take the SD card out of the system and plug it into a computer 5. Find the size of the file that

		was created by the system during those 6 hours. 6. Multiply that size by 744 to get the amount of space that would be taken up in 6 months of operation (4 6-hour segments per day * 31 days per month * 6 months, 4*31*6 = 744) 7. Compare that size with 80% of the total size of the SD card, and verify that it is less
3	The system will accurately monitor water flow within +-20% for 6 hours.	Method: Demonstration 1. Place the pressure sensor at the bottom of a stream of water that has a known volumetric flow 2. Power on the field system 3. Begin collecting data on office part of the system 4. Let the system run for 6 hours 5. Stop collecting data on the office part of the system 6. Calculate the water flow based on the readings that were taken. 7. Verify that the calculated readings are within +-20% of the known flow rate
4	The system will have a data transmission range of 1km in normal operations, with a clear line of sight.	Method: Demonstration 1. Set up the system and move the receiver to a location 1km away with a direct line of sight. 2. Verify using a test script that data is being received.
5	The system will be ruggedly enclosed	Method: Inspection 1. Locate a water nozzle (shower head) in order to spray low pressure water jets at the enclosure. 2. Place water detection paper strips inside the enclosure around the perimeter, and on electronics. 3. For 3 minutes, spray direct water jets onto the enclosure from the water nozzle (shower

		head). 4. After 3 minutes, turn off the water, and dry off the enclosure to clear excess water. 5. Inspect the interior of the enclosure. Ensure that no water has entered the enclosure, electronics are still working, and water detection strips are dry.
6	The system will allow for user defined inputs.	Method: Demonstration 1. Open the user interface 2. Enter in gate parameters 3. Verify that the calculations for water volume are adjusted based on inputs.
7	The system will display the recorded data.	Method: Demonstration 1. Open the user interface 2. Verify that the volume is displayed
8	The system contains a user manual with information on field system setup.	Method: Inspection 1. Look at the user manual and verify that it contains information on system setup.

2.2 - Design Impact Statement

1.0 Introduction

The goal of the Farming in the Climate Change Era project is to deliver the Quechan Indian Tribe a field system that will measure and record instantaneous flow of water through irrigation gates. The recorded data will be used by irrigation and water managers to track the progress of watering each day. In addition, the data will be stored in a user interface in order for the tribe to track water usage throughout the year and also to report usage to the California government. This report will serve as a comprehensive analysis of the impacts and risks of the system, to be used as a reference for guiding the design of the system.

There are several notable impacts of designing this system; the significance of these impacts must be considered exhaustively. As a designer, every aspect of the system must be fully understood, including the direct and indirect impacts of the system, particularly, the negative impacts. The designer is responsible for the system and everything it interacts with; if these interactions are not positive, measures must be taken to reduce or eliminate those consequences. The research presented in the following pages will include background knowledge, negative impacts, and risks of our prototype. There are several impacts that must be explored. To begin, the Quechan Indian Tribe is 3,000 members strong, and they provide food and shelter to their families by producing agricultural products. This prototype will help serve that purpose and allow for more efficient and effective water use and management; however, this requires that electronics are in the water, leading to inherent safety hazards. Water pressure monitoring involves adding more sensors and electric material into our waterways. If improperly designed, the system may leave hazardous material in drinking water and dangerous electric currents flowing without protection. In addition, the tribe is located near the United States/Mexico border, and the land they work must be irrigated year-round. Water managers work long hours, leading to safety risks while in the field. Our team lacks Native American diversity in our members, so we risk unintentionally having a bias in our system towards subgroups of people. Lastly, our prototype will serve as a low cost alternative to the expensive existing solution. It will be more attainable for the tribe; however, it will also be taking away from an existing company's market share of the water flow monitoring industry. This means that copyright and patent laws must be carefully considered. Overall, the impact of our design is monumental on the tribe and the Earth's ecosystem.

2.0 Public Health, Safety, and Welfare Impacts

The central group of people that would be impacted by our system is the Quechan Indian Tribe. The tribe's total population is over 3,000 members, and the core focus of its members is agriculture. The tribal land is located in Imperial Valley, a region of the Sonoran Desert in southern California very near to the Mexican border. This area only sees 3 inches of precipitation per year, so the crops and fields must be irrigated year-round. To accomplish this, many regions of California use large irrigation ditches.

Figure 1: Irrigation Ditch

As shown in figure 1, these ditches run through the fields, and they have gates that can be open and closed to control which field is being watered. The tribe water managers work 24-hour shifts to control these gates. These workers are often exhausted during their shifts, and this leads to variability in water application, and also major errors that can cause waste or crop loss.

Our system directly aids these water managers in several ways. First, the system aims to provide a way to monitor the volume of water that has flowed through a gate. This information will be readily accessible to the water managers and can even be used to notify them when a gate needs to be opened or closed. The readily available data allows the water managers to have a reduced workload and therefore a safer job environment. According to the National Safety Council (NSC), about 13 percent of workplace injuries are directly related to exhaustion and lack of sleep; these accidents generate roughly $400 billion in damages to the economy each year [1]. Not only will the employees be safer, but also the crops will receive more consistent and more accurate doses of water. Our project partner and Quechan Tribe member, Garrad Jones, has explained that sometimes the gates are left open and the water continues to flow for much longer than necessary, flooding the field and wasting millions of gallons of water. Over-watering, and of course under-watering, cause immense damage to crops around the world each year. A recent study highlighted that each year over 8 billion dollars in economic losses come from soil erosion, which is a result of rapidly overwatering [2].

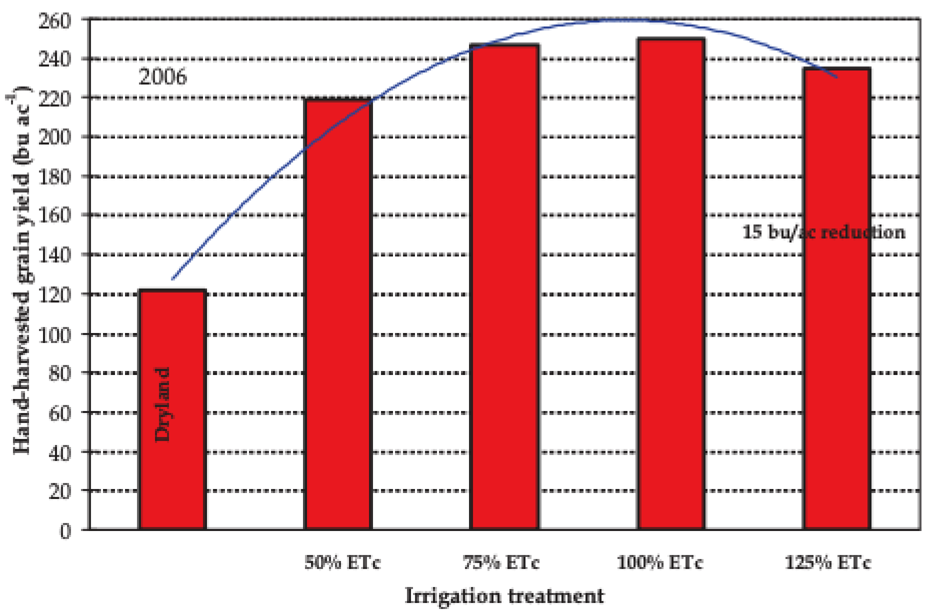

Figure 2: Crop Yields vs Irrigation Rates

Figure two comes from a University of Nebraska article on crop losses due to irrigation rates [3]. The figure exhibits that the prime production in crops is when they are supplied the necessary amount of water, and too much water can actually be worse than too little water. The Quechan tribe relies on crop yields to provide income to its members. These inconsistencies in water rates can be costly mistakes that lower yields, and in turn, lower income. A malfunction in our system risks returning to the poor practices of water application that were employed. Overworking the employees and causing millions in crop damage. The integrity of our system is paramount, and understanding the risks of failure or inaccurate information allows us to more carefully design the system with these things in mind.

Crop production is not the only financial factor in this water waste; the state of California is imposing strict water usage laws due to the record lows of the Colorado river. The Bureau of Reclamation is now requiring that the tribe water operators must provide flow data through their irrigation gates. At the present moment, this data does not exist; there is nothing measuring and recording the flow of water into the fields. The clock is ticking and sooner or later, government pressure will turn into government penalties for not reporting water usage data. Our prototype will collect this data and allow for the tribe to avoid paying fines or purchasing very costly alternative systems. Once again, a failure in our system could cost the tribe massively in fines, meaning our system must be dependable.

In terms of safety, electronics in water is always a delicate subject. The impurities in water cause it to conduct electricity, and anything touching the water will also then be in contact with live power.

Our system will require that certain powered electronics and sensors are submerged into a waterway. Without proper insulation and protection, power could be released into the water, causing a deadly threat to humans that have to operate the gates. This is one of the paramount factors of consideration when designing this system: encapsulation and safety in the water. The system must be ruggedly designed in order to withstand trauma, so that the electrical system remains out of contact with water. Even if someone steps on the system, slams the gate on the sensors, drops the enclosure on concrete, or drops the entire unit into the ditch, the system must remain watertight in order to protect the operators. According to the Centers for Disease Control's National Safety Council, there are over 300 deaths and 4000 injuries from electric shock each year [4]. The main focus of our system is to keep safety for the users and water managers at the forefront; the presented research allows our design team to make adequate adjustments based on mitigating risks and negative impacts.

With this knowledge, our system can be designed in a more adequate way to address these concerns and risks. The first recommendation for this impact area would be to make the focus of the user interface in our system designed to aid these water managers as efficiently as possible. The data shows that workplace exhaustion is a real risk, especially in workplaces with safety hazards all over. The more time we can save these individuals with our interface, the less hours they need to spend out in the field. This means our user interface must be user friendly, easy to navigate, and show the important information effectively. In addition, our system must be created with reliability and dependability in mind, because a failure would prove to be catastrophic in several areas. In order to reduce this risk, premium parts and maintenance manuals must be included. This also requires that our data storage system be refined and make use of a memory that is not going to become corrupted. The second recommendation from this exploration would be to actively design the enclosure to be as rugged as possible. This stems from the electrical risk of having live currents in open waterways. Farm workers frequently interact with these canals, so even one mistake in this segment of the project produces a catastrophic impact. Therefore, our system will be designed to function normally underwater with no exposed electrical connections. All connections will use IP68 certified connectors. Furthermore, to verify the system's IP68 rating, our system will undergo thorough testing according to the IP68 standards. These two recommendations will further solidify our system as safety oriented according to the public health risks research conducted.

3.0 Cultural and Social Impacts

Native American people are one of the most ostracized groups in United States history, and the risks of cultural bias are still apparent. The oppression that Native Americans have faced throughout our country's history is well detailed [5]. When English settlers first came to the Americas, which the Native Americans already occupied, the English did not respect the tribes or their land. Many tribes were completely extinguished due to either war or disease. Congress has put in place measures to give back to the native people, but the act is far from generous. Many issues still surround the indigenous people to this day. There are hosts of studies done each year that find that some of the highest rates of discrimation are towards Native Americans. Over 26 percent of indeginous people live below the poverty line, compared to the national rate of about 14 percent. In the past few years, activists have become more vocal to advocate for this often overlooked and under-represented group. Our team hopes that it can provide a low cost solution that will benefit a group of individuals that are in need of reparations.

Unintentional bias is an issue in engineering that is being addressed more, and it poses a risk for this project. [6] None of the members of our design team are Native American, so the team lacks perspective in that category. In engineering, code bias is when the design of a system does not take into account how it might differently affect people of color, people from different backgrounds or people from different socioeconomic upbringings. Some examples of this are when AI cannot recognize faces of people of color, while it can recognize white people faces with ease. Often the cause of this issue is that a predominately white team designed the code, and the lack of diversity led to neglecting the issue of representation. This problem did not stem from blatant racism or hatred, it was merely a lack of perspective from the designers. This research can be used to aid our design and design process to overcome this lack of perspective. Without a Native American viewpoint, code bias is certainly a risk to our team that must be discussed and mitigated.

The best way to make up for a lack of perspective on a team is to add someone with the missing perspective. Fortunately for our team, we have the perfect resource: Gerrad Jones, our project partner. Gerrad is a member of the tribe and he works with our team to make the most useful end product for the tribe. In order to mitigate the risk of code bias, we will work with Gerrad to make sure that our system is usable by people from all backgrounds. This will be done with thorough testing and documentation, along with a design process that includes insight from people of all backgrounds.

4.0 Environmental Impacts

The central environmental impact of our system is inherently positive, but not without risks that must be considered. Any flow data that can be used to create a more efficient irrigation system will reduce waste, and our prototype aims to collect a host of data to achieve that very goal. As aforementioned, the tribal land is located in the Sonoran Desert, and must be irrigated year round because the region only receives about 3 inches of rainfall per calendar year.

The water for the fields comes from the All-American Canal, an 82 mile long aqueduct that supplies water to nine cities in southern California. The Imperial Irrigation District website explains that the canal provides water to irrigate over 500,000 acres, and it has transformed one of the driest areas on the planet into one of the top agricultural producers [7]. In addition, the canal features eight power plants, combining to produce 58 MW of power. The water for the canal is supplied from the Colorado River. The Colorado River is a legendary river that carved out portions of the western United States. The 1,450 mile long river runs through six states and into Mexico, passing through the Grand Canyon on the way. It also supplies two of the nation's largest water storages, Lake Powell and Lake Mead; furthermore, the river acts as the primary water source for many major cities, like Las Vegas, San Diego, Phoenix, and Los Angeles. This is drinking water for 40 million people. An American Rivers column details that the river is severely in deficit because of recent droughts and global warming [8]. Lake Powell and Lake Mead are also critically low. Both lakes have dropped over 100 feet over the last decade, and are now only 30% full. The shortage is documented in extensive detail, including the water restrictions that are being put in place to reduce usage and waste from the Colorado River, like the restrictions that are being put on the tribe [9]. Our prototype is designed to minimize water usage and allow for precisely the right amount of water to be applied; which, in turn, relieves pressure from the river that is so direly in need of a break.

The downside of complex microcontrollers and sensors that collect water data is that the tools need to be in the waterways, which means that there will be many metals and plastics submerged in water that is used for drinking. Each year, hundreds of thousands of people die from poor quality drinking water [10]. This poor quality water comes from many factors, which include dumping, oil spills, trash contaminants, sewage, and agricultural contamination. As previously mentioned, the system our team is designing is safety oriented, and it will be ruggedly designed in order to minimize contamination and pollution. The system will all be enclosed, and the enclosure will be completely water safe. In addition, it will also help to counteract the water contamination pollution, which occurs when agricultural water is returned to waterways with chemicals from the field. This water makes it back to waterways when a field floods, which is an issue for the Quechan tribe. Our system will be used to notify water managers when a field is completed in order to minimize the risk of flooding and contamination. In the long run, although our system is adding plastics and metals into a waterway, it will be designed in a manner to keep all pollutants at a minimum, and its functionality will provide aid to one of the most important rivers in North America.

This exploration leads to a key part of the design process that must be considered, the materials that are used in the enclosures. Since our system is in the water, each and every component must be certified RoHS safe and contain no lead. Our team will research the materials that we can use for a rugged enclosure and use the one that adds the least amount of toxins and waste into these waterways. These safer materials will prevent toxins entering drinking water, agricultural areas, and wildlife in the water. Environmental safety is paramount to our system, and adding toxins to our waterways would effectively cancel out any positive benefits of our system. Overall, the research conducted here will be used to design a more safe and well thought through system that will leave a minimal footprint on the environment.

5.0 Economic Factors

There are two economic factors at play with our prototype. The first is that our system competes directly with a different company. The tribe needs a way to monitor water usage, and that is water our system is meant to do; however, there are already existing systems that can do this, but they are extremely costly. Rubicon Water manufactures state of the art systems that optimise irrigation [11]. Our system is a direct competitor, and if the tribe decides to use the system, Rubicon Water has lost a potential customer. Our design will impact this company, likely in just a minor way, but it will have deterred a customer and changed the flow of funds to our system instead. In taking market share from the company, we need to make sure our design is not violating any copyright laws. This will require research on existing technology and a complete understanding of what we can and cannot have in common with this competitor's design.

The second driving economic impact is that our system will create job loss because of automation. The Colorado River adds $1.4 trillion dollars in yearly economic activity to the economy, including 16 million jobs across several states, which equates to approximately 1/12th of US GDP [12]. A 10 percent drop in the water level of the river results in 1.6 million jobs lost and $143 billion in economic losses. While our system does save jobs by reducing water waste, it also causes job losses due to an increase in efficiency. While fully incorporated, our system makes the water management process much more efficient, therefore requiring less employees. As of right now, there are many individuals that work long hours to monitor the application of water. With our system, this data can be recorded automatically and only one person is needed to monitor the application of water on several fields. Without the need for these other water managers, the tribe will need to eliminate those positions.

With this research in mind, there are two key recommendations for the design phase of the project. First, knowing that there is a direct competitor means that there will be limitations on how similar our designs can be. We will research the other company’s design and take into account all copyright laws. This will prevent any infringement and allow for our design to be fully independent and unique. The second recommendation is that our project will consider the job losses of the other individuals who currently manage the water application. Although our system cannot prevent these losses, we will use this knowledge to create an opportunity for these individuals to transition into a new role in water management. Our system will need someone to monitor the water application data that is provided of course, but it will also need installation and maintenance. Our design will have thorough detail on how to install and maintain the system so that the people who are no longer needed in water management can focus on the maintenance of the system and other aspects of the agriculture process.

6.0 Conclusion

Ultimately, the acknowledgement of these impacts and risks help us to design a product with a more accurate viewpoint on its requirements. There are several key recommendations derived from the discussed research that will be implemented in the design of the system. First, our user interface must be as simple, yet effective as possible, saving time for overworked managers and allowing the data to be organized in a practical way. Next, it is of utmost importance that our system is safety-oriented. This means we must build a rugged system that is 100% safe in water, and that the encapsulation of the device is not covered in harmful toxins. This requires RoHS certified components and IP68 rated enclosures and connectors. The water that our design will be able to save will take pressure off of the Colorado River, and it will allow more effective and safe agricultural production for the tribe. While designing the prototype, our lack of Native American perspective is acknowledged and will be mitigated with the help of our project partner. Creating a design with insight from people of all backgrounds will allow for our system to reduce any potential unforeseen biases towards any subsection of people. Furthermore, the system will also allow the Quechan people to satisfy government requirements on water data, without needing to purchase an expensive alternative; however, the copyrights and patents of our competitor will need to be taken into account to allow for a fully unique and legal system to be created. In addition, our documentation will be created with intent to be used as a manual for the water managers to use as a guide for installation and maintenance. This will allow employees that are no longer needed to directly manage water to transition to a different role in the process more effectively. Overall, our team is excited to embark on the prototype design, with the goal of satisfying the needs of the Quechan people, while incorporating this research to ensure that the system has minimal negative impacts and risks on those around it.

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landscapes/colorado-river/economic-importance-of-the-colorado-river/. [Accessed: 29-Oct-2021].

Date	Revision
10/23	Draft: Initial Release
10/18	Updated Formatting and Citations
10/22	Revisions based on feedback, refocused paper on negatives
10/26	Final Updates, revisions based on feedback

2.3 - Risks

Table 1. Risk Assessment and Action Plans

ID	Description	Category	Probability	Impact	Performance indicator	Responsible party	Action Plan

1	Component Delays	Components	H	H	Shipping times	Alex	Avoid Last minute purchases
2	Communication Error	Assembly	L	M	Workflow	Eric	Retain meeting notes
3	Cost increase	Components	M	M	Budget	Nick	Transfer more budget allocation
4	Delay in smartrock tech	Components	L	H	No smartrock	Luiquio	Reduce reliance on Smartrock
5	Incorrect Components	Components	M	L	Lost Time waiting for new components	Alex	Transfer more focus to finding new parts
6	Covid-19 Resurgence	Health	M	M	Covid-19 Rates in Oregon	Eric	Transfer all meetings to be via zoom.
7	Project Partner not communicating	Design	L	M	Monitor communication and relationship with Gerrad	Nick	Reduce dependency on Gerrad for design details, attempt to meet the goals we have already set.
8	Parts Failure	Components	L	H	Make sure to study the datasheet to ensure parts will work as intended	Luiquio	Retain, remove the part from the system and retain as much as we can as long as it is not damaged.

2.4 - References & File Links

2.4.1 - References

Texas Instruments Linear Charge Management IC for Lithium-Ion and Lithium-Polymer https://www.ti.com/lit/ds/symlink/bq2057.pdf?HQS=dis-dk-null-digikeymode-dsf-pf-null-wwe&ts=1637297063277&ref_url=https%253A%252F%252Fwww.ti.com%252Fgeneral%252Fdocs%252Fsuppproductinfo.tsp%253FdistId%253D10%2526gotoUrl%253Dhttps%253A%252F%252Fwww.ti.com%252Flit%252Fgpn%252Fbq2057

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2.4.2 - File Links

https://drive.google.com/drive/u/1/folders/0AIfETVwsId-rUk9PVA

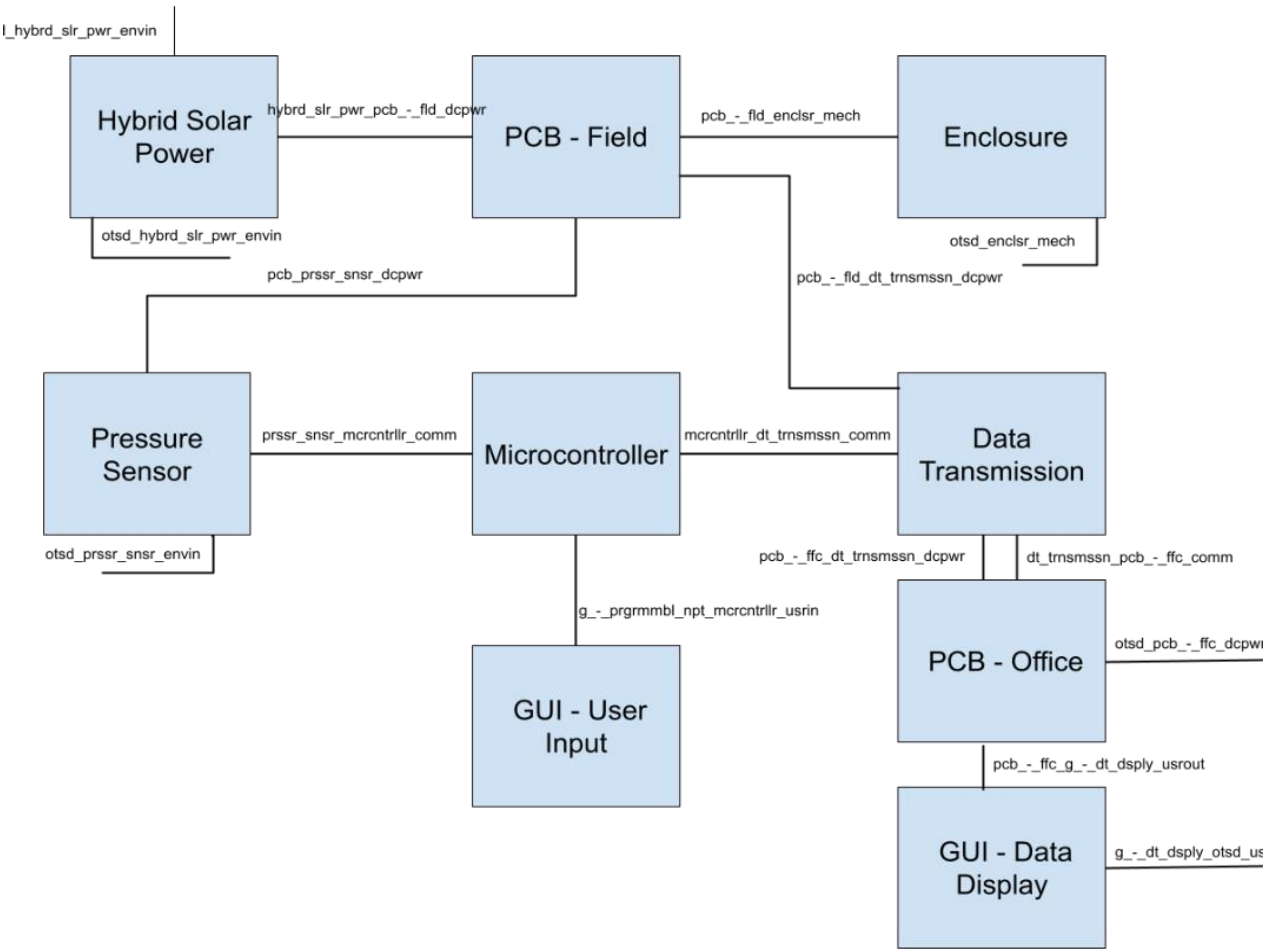
2.5 - Revision Table

Date	Changes
10/27	Added Section 2

11/9	Eric van Klaveren: Updated requirements
11/11	Eric van Klaveren: Updated Risks
11/12	Eric van Klaveren: Added references and links
11/12	Nicholas Ung: Added additional engineering requirements and verifications, edit to formatting
11/12	Alexander Eamons: Updated references to IEEE format
11/18	Eric van Klaveren: More updates from feedback, updating risk
11/19	Nicholas Ung: added reference datasheet for battery charging IC
11/19	Liuqiao Song: add descriptions of PCB and GUI block
12/1	Eric van Klaveren: Added/Updated Risks
12/2	Eric van Klaveren: Updated Requirements based on feedback

3 - Top Level Architecture

3.1 - Block Diagram



3.2 - Block Descriptions

3.2.1 - Microcontroller

Champion: Alexander Eamons

Summary:

The microcontroller takes and records the pressure data sent from a pressure sensor in the form of a digital value transferred with SPI transmission. It then uses those pressure values as well as channel values such as its shape and slope which are programmed into the device to determine the flow rate of the channel which the pressure sensor is submerged in by use of the Manning's Equation.

3.2.2 - Pressure Sensor

Champion: Alexander Eamons

Summary:

The MS5803 pressure sensor built into the SmartRock device designed by the "Openly Published Environmental Sensing Lab at Oregon State University". This device will detect the pressure of the water it is submerged in, and convert that to a digital value using a built in ADC and send that digital value to a microcontroller via Two Wire I2C communications to be interpreted and used for further calculations.

3.2.3 - User Interface - Data Display

Champion: Liuqiao Song

Summary:

The user interface is the last module of the entire project that we have made. It can be an application or an interface, or a display screen to display the changes in regional water volume or the water pressure at a time. The user interface is widely defined. Including human-computer interaction and graphical user interface, user interfaces exist in all fields that participate in the information exchange between humans and machines.

3.2.4 - User Interface - Programmable Input

Champion: Liuqiao Song

Summary:

The programmable input block will take in user input and relay it to the PCB office. This needs to be done so that the system can be universally placed in any irrigation gate. This input will be the dimensions of the gate, length, width and height. This data will be sent to the data interpretation block so that the calculations can be based on accurate and specific dimensions. This will involve an interface on an application. And the format of the interface could be done in software like Matlab.

3.2.5 - PCB - Field

Champion: Eric van Klaveren

Summary:

The water flow monitoring system has two custom PCBs in the design, one in the field monitoring water flow, and the other in the office displaying data. The purpose of the field PCB is to house a microcontroller chip to control the water monitoring system. The PCB will hold the Arduino Nano microcontroller, but it will also house some connectors for the LORA transmitter and the pressure sensors, along with some passive components. The field PCB interfaces with 4 other blocks; it receives power from the hybrid solar power unit and has a mechanical connection to the enclosure. In addition, it communicates and supplies power to both the wireless transmitter and the pressure sensor. This PCB will be out in a field near the pressure sensor so that it can record data and then send it off to the transmitter and to the office PCB.

The PCB will be designed in EasyEDA, a custom PCB software tool. The schematics will be designed, then transferred over into PCB form, where they will be laid out and traces will be connected. Finally, the PCB will be exported as gerber files and ordered from a custom PCB manufacturer.

3.2.6 - PCB - Office

Champion: Eric van Klaveren

Summary:

The office PCB will serve a very similar purpose to the field PCB. It will house an Arduino Nano microcontroller, and it will have a connector to the wireless receiver and an area for the micro-USB cable to be plugged into the Arduino for data display. This PCB will be located in an office where water managers monitor flow data. It will house a device that will be plugged into a computer in order to show the received sensor data.

The PCB will be designed in EasyEDA, a custom PCB software tool. The schematics will be designed, then transferred over into PCB form, where they will be laid out and traces will be connected. Finally, the PCB will be exported as gerber files and ordered from a custom PCB manufacturer.

3.2.7 - Enclosure

Champion: Nick Ung

Summary:

The enclosure to our system must be rugged enough to weather outdoor conditions, as it will be located near the field devices at the irrigation gates themselves. In order to meet these requirements, this enclosure will be tested for IP65 verification. According to the IEC, to verify water protection, the enclosure must withstand a water jet from any angle at a flow of 12.5 liters per minute, at 4.4 PSI, from 9.8 feet away.

3.2.8 - Hybrid Solar Power

Champion: Nick Ung

Summary:

The power delivery to the system will consist of a hybrid solar battery system. This hybrid system revolves around the TP4056 battery charging IC. This allows for simultaneous passthrough power and battery charging. While there is enough sun to source solar energy, the produced voltage will be distributed through the IC to the Arduino and field devices, as well as the 18650 lithium batteries for storage. The intent of this system is to incorporate enough mAh of storage to where the system can be self-sufficient off of solar alone. This capacity will be determined through various stress testing. When there are not appropriate conditions for solar power to be generated, the IC will allow for the batteries to discharge and provide power to the devices. This hybrid solar power supply will exist on a custom PCB that will distribute 5V and 3.3V to our system.

3.2.9 - Data Transmission

Champion: Eric van Klaveren

Summary:

The purpose of the data transmission block is to send sensor data wirelessly from a transmitter to a receiver. This block interfaces with three blocks in the project, the Field

PCB, the field microcontroller, and the GUI microcontroller. The transmitter receives power from the Field PCB and the transmit signal from the field microcontroller. The receiver gets power from the GUI microcontroller, and also sends the received signal to this microcontroller. The transmitter and receiver are REYAX RLYR896 LORA transmitters. They communicate using UART and the built in LORA communication RF protocol. The transmission is unidirectional, only from transmitter to receiver.

The transmitter unit will be in charge of sending out data to the GUI unit from the sensor. It will receive the data from the field microcontroller; this means it will be out in the farm where the data is being collected. In order to get the data out to the water managers, it will send out data via an antenna that is elevated to avoid obstructions. The transmitter will receive binary data via UART, and translate it to the LORA protocol, and then send that data via RF waves. These waves are electromagnetic pulses that are modulated by the transmission chip to match the LORA protocol.

The receiver will be in a location that is not in the field, likely a nearby office. It will be connected to an antenna that is also elevated to avoid obstructions just like the transmitter. The data will be received and translated from an RF signal modulated in the LORA protocol, to demodulated UART binary data that can be interpreted by the GUI microcontroller that handles the user interface. This data will then be displayed for the water managers to view.

3.3 - Interface Definitions

Name	Properties
otsd_hybrd_slr_pwr_dcpwr	Inominal: 130mA Ipeak: 500mA Vmin: 4.2V Vnominal: 5V
otsd_enclsr_mech	Fasteners: M4 Standoffs Fasteners: Strut Railing to mount enclosure to wall, post, etc. Other: IP65 Water Resistance
otsd_prssr_snsr_envin	Other: Barometric Pressure: ~1 atm Water: Depth: 0-0.3m Water: Pressure: 0-0.03 Bar
otsd_pcb_-_ffc_dcpwr	Inominal: 100mA Ipeak: 500mA Vmax: 5.1V Vmin: 4.9V
hybrd_slr_pwr_enclsr_mech	Fasteners: Included screws to be used to fasten solar panel to post Fasteners: Stands located in the enclosure and matching standoff holes to secure PCB to enclosure Other: Passthrough will be an M13 style connector with IP67 or greater resistance
hybrd_slr_pwr_pcb_-_fld_dcpwr	Inominal: 50mA Ipeak: 100mA Vmax: 5.1V Vmin: 4.9V
prssr_snsr_mcrcntrllr_comm	Datarate: 400 kHz Protocol: I2C Vnominal: Logic Low - 0V Vnominal: Logic High - 3.3V
dt_trnsmssn_pcb_-_ffc_comm	Datarate: Baud Rate: 115,200 Other: Logic Level: Active High Other: Logic Level: 3.25V
mcrcntrllr_dt_trnsmssn_comm	Datarate: Baud Rate: 115,200 Other: Logic High - 3.3V Other: Logic Low - 0V Protocol: UART
pcb_-_fld_enclsr_mech	Fasteners: M4 Bolts Other: Length - 4.9in Other: Height - 2.5n

pcb_-_fld_prssr_snsr_dcpwr	Inominal: 8 µA Ipeak: 32 uA Vmax: 3.6 V Vmin: 1.8 V
pcb_-_fld_dt_trnsmssn_dcpwr	Inominal: 15mA Ipeak: 75mA Vmax: 3.5V Vmin: 2.9V
g_-_dt_dsply_otsd_usrout	Other: Data from at least previous 24 months Other: graph of water level
g_-_prgrmmbl_npt_mcrcntrllr_usrin	Other: <32kB Other: Plaintext Other: Length Width Height Information
pcb_-_ffc_dt_trnsmssn_dcpwr	Inominal: 15mA Ipeak: 75mA Vmax: 3.5V Vmin: 2.9V
pcb_-_ffc_g_-_dt_dsply_usrout	Other: minimum of 2 region to monitor Other: 2 years of data Other: water level value

3.4 - References and File Links

3.4.1 - References

"What is Lora®?," *Semtech*. [Online]. Available: https://www.semtech.com/lora/what-is-lora.

E. C. Martin, "Measuring Water Flow in Surface Irrigation Ditches and Gated Pipe," *arizona.edu*, Dec-2011. [Online]. Available: https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1329.pdf.

OPEnSLab-OSU, "Home · OPEnSLab-OSU/smartrock wiki," *GitHub*. [Online]. Available: https://github.com/OPEnSLab-OSU/SmartRock/wiki.

3.4.2 - File Links

https://drive.google.com/drive/u/1/folders/0AIfETVwsId-rUk9PVA

3.5 - Revision Table

Date	Changes
11/15	Eric van Klaveren: Created new section
11/15	Eric van Klaveren: Added Block Description
11/15	Nicholas Ung: Added Block Descriptions
11/16	Alexander Eamons: Added Block Descriptions
11/18	Eric van Klaveren: Added Interface definitions table
11/19	Team: Added block diagram
11/19	Liuqiao Song: add descriptions of PCB and GUI block
12/1	Nicholas Ung: revisions to section 3.2.6, 3.3
12/2	Eric van Klaveren: Revised Blocks and summaries
12/2	Nicholas Ung: Revisions to interface definitions and properties table
12/3	Team: Final Block Diagram

4 - Block Validations

4.1 - Data Transmission

4.1.1 - Description

Champion: Eric van Klaveren

The purpose of the data transmission block is to send sensor data wirelessly from a transmitter to a receiver. This block interfaces with three blocks in the project, the Field PCB, the field microcontroller, and the GUI microcontroller. The transmitter receives power from the Field PCB and the transmit signal from the field microcontroller. The receiver gets power from the GUI microcontroller, and also sends the received signal to this microcontroller. The transmitter and receiver are REYAX RLYR896 LORA transmitters. They communicate using UART and the built in LORA communication RF protocol. The transmission is unidirectional, only from transmitter to receiver.

The transmitter unit will be in charge of sending out data to the GUI unit from the sensor. It will receive the data from the field microcontroller; this means it will be out in the farm where the data is being collected. In order to get the data out to the water managers, it will send out data via an antenna that is elevated to avoid obstructions. The transmitter will receive binary data via UART, and translate it to the LORA protocol, and then send that data via RF waves. These waves are electromagnetic pulses that are modulated by the transmission chip to match the LORA protocol.

The receiver will be in a location that is not in the field, likely a nearby office. It will be connected to an antenna that is also elevated to avoid obstructions just like the transmitter. The data will be received and translated from an RF signal modulated in the LORA protocol, to demodulated UART binary data that can be interpreted by the GUI microcontroller that handles the user interface. This data will then be displayed for the water managers to view.

4.1.2 - Design

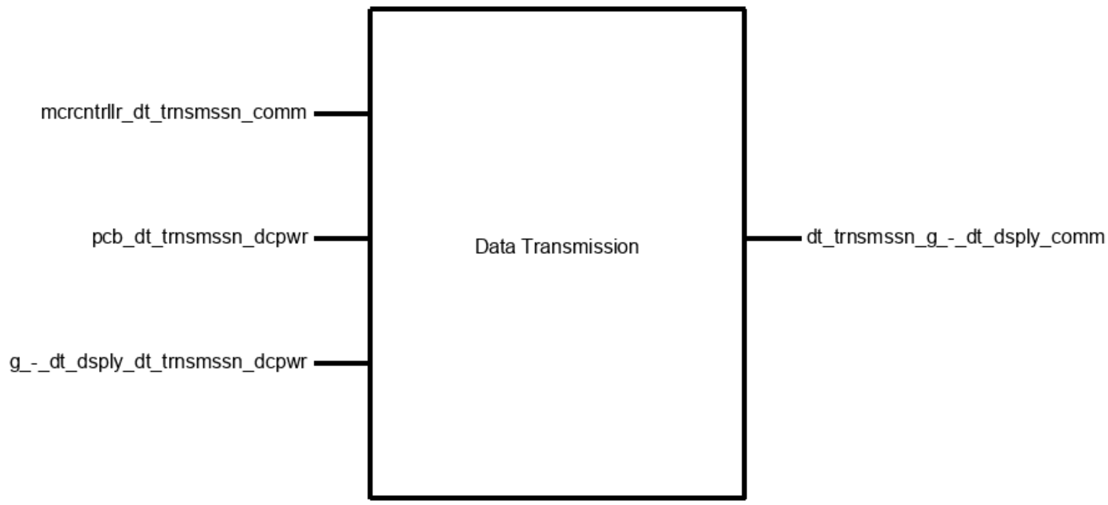


Figure 1 - Black Box Diagram

Figure one shows the black box diagram with all 4 interfaces.

Pcb_dt_trnsmssn_dcpwr - This is the 3.3V power from the PCB to the transmitter.

G_-_dt_dsply_dt_trnsmssn_dcpwr - This is the 3.3V power from the GUI microcontroller to the receiver.

Mcrcntrllr_dt_trnsmssn_comm - This is the UART communication line from the field microcontroller to the transmitter.

Dt_trnsmssn_g_-_dt_dsply_comm - This is the UART communication line from the receiver to the GUI microcontroller.

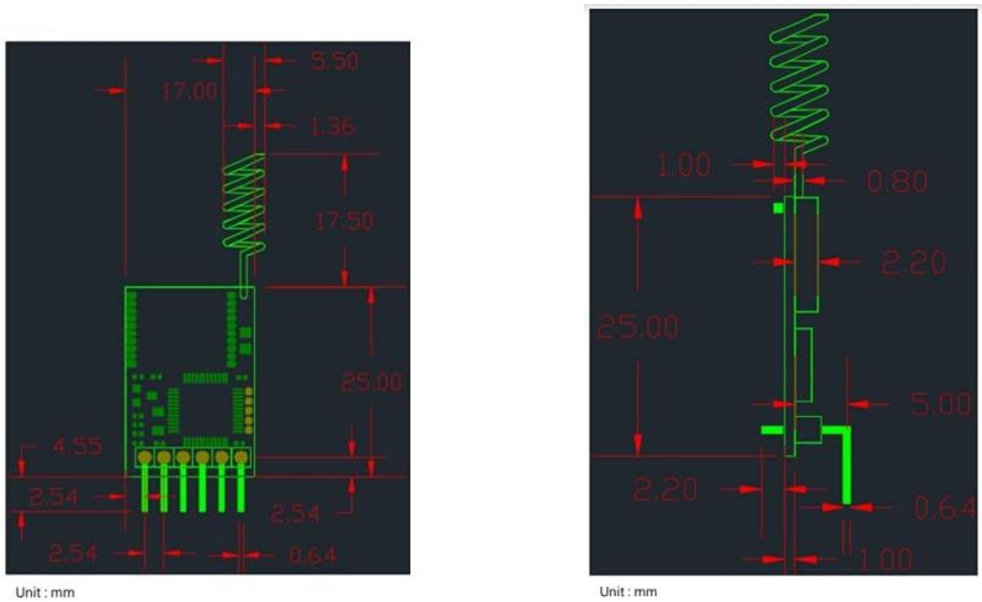


Figure 2 - Transceiver Front and Side Mechanical Drawings

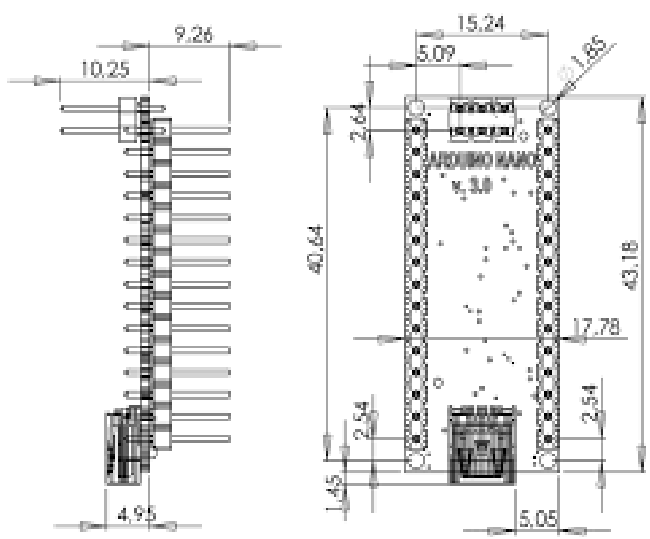


Figure 4 - Arduino Nano Microcontroller Mechanical Drawing

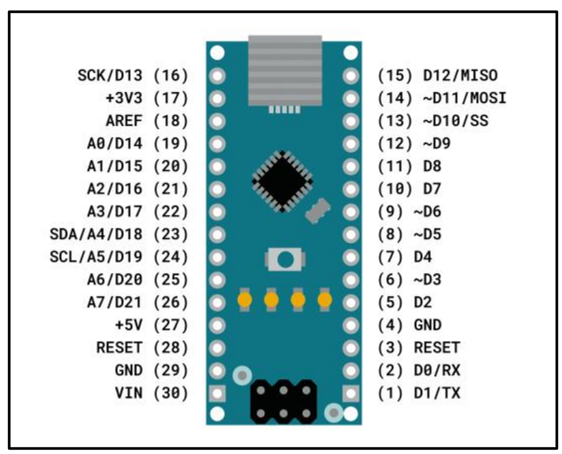


Figure 5 - Arduino Nano Pinout

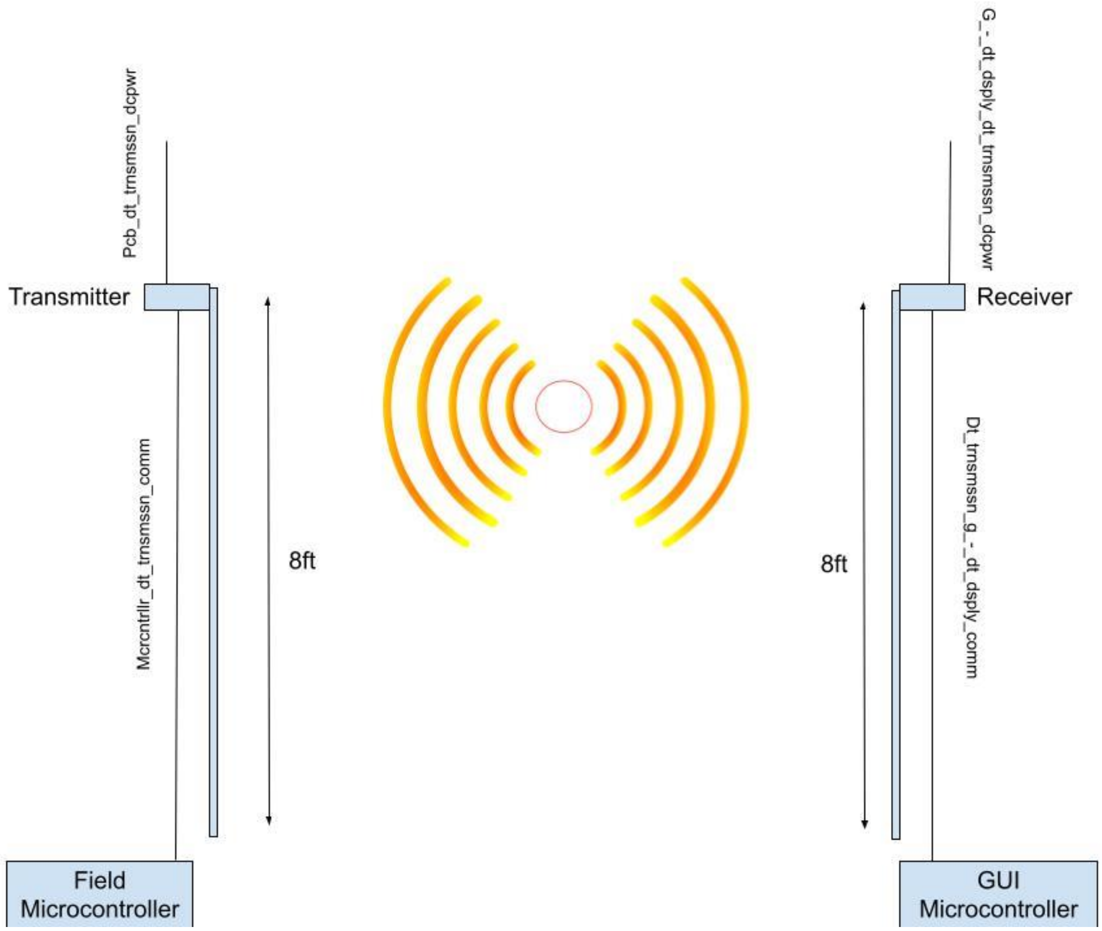


Figure 6 - Physical Diagram

Figure 6 shows how the physical block will be set up. Each of the transceivers will be mounted to an 8ft tall post so that they can have some elevation to allow for further and more reliable transmission. The first transceiver will be programmed by the microcontroller to transmit data and be powered by the PCB. These are the two transmitter interfaces. It will transmit an incrementing number to the second unit, which is placed at a maximum distance of 1,000m, using the LORA protocol. The second unit will be programmed as a receiver to retrieve the transmitted signal, the incrementing numbers, and then display it to the serial monitor to allow for verification of transmission. The receiver is connected to the GUI microcontroller for power and to send the received signal, these are the two receiver interfaces.

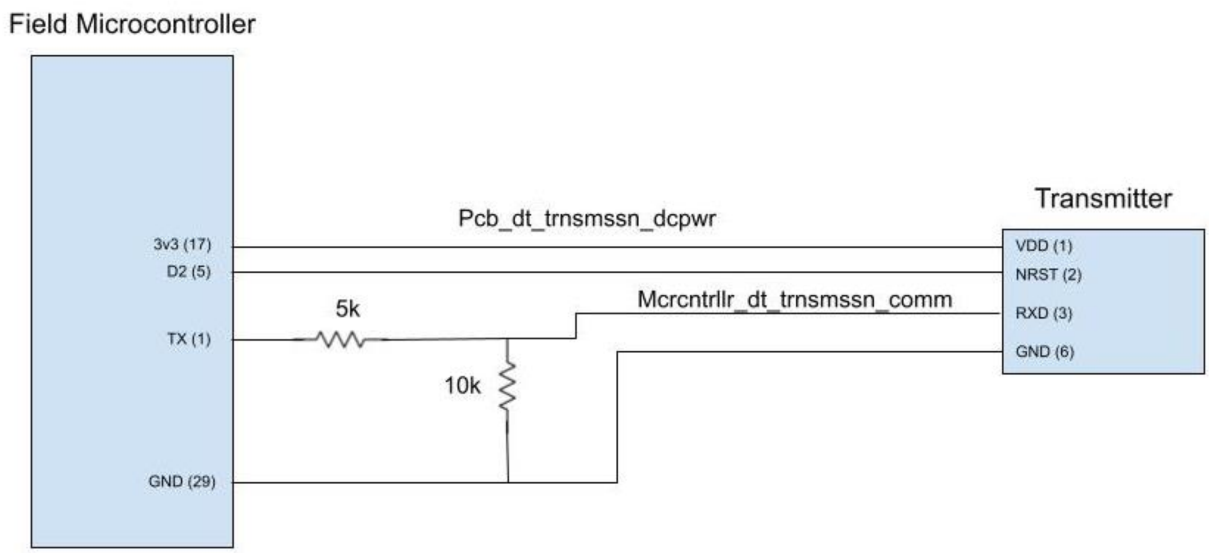


Figure 7 - Transmitter Wiring Diagram

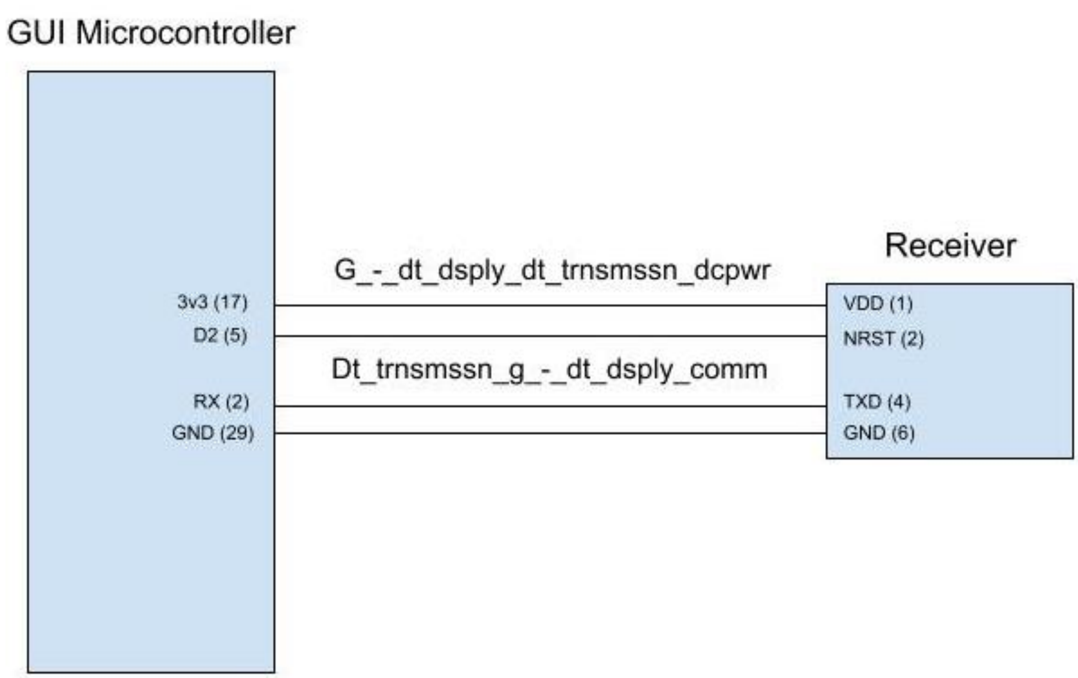


Figure 8 - Receiver Wiring Diagram

Figure 7 shows the wiring diagram and interface connections of the transmitter portion of the data transmission block. The Field Microcontroller sends a UART signal to the transmitter from TX to RX. The voltage divider is in place because the microcontroller operates at 5V, and the maximum input for the transmitter is 3.6V.

Figure 8 shows the same wiring diagram but for the receiver. There is no voltage divider necessary because the receiver sends data at 3.3V, and the microcontroller can accept that voltage.

Code:

AT Commands: Before programming the receiver and transmitter microcontrollers, the transceivers need to be programmed with some settings. The REYAX RYLR896 AT Commands document details the many AT commands available. In this case, the network ID, address, band, and parameters needed to be set. All of the other settings were left at default. [1]

Transmitter:

Address: 1
Network ID: 6
Band: 868,500,000 Hz
Parameters:
Spreading Factor: 12
Bandwidth: 15.6 KHz
Coding Rate: 4
Preamble: 4

Receiver:

Address: 2
Network ID: 6
Band: 868,500,000 Hz
Parameters:
Spreading Factor: 12
Bandwidth: 15.6 KHz
Coding Rate: 4
Preamble: 4

The address is the transceiver's unique identity. The network ID is the network that the transceivers share. The band is the North American LORA frequency band. The spreading factor is set to 12 because that is the highest, leading to maximum range. The bandwidth is 15.6 KHz because that is the lowest, for max range. The coding rate is at 4, for maximum reliability and the preamble is at 4 because it is the default.

```
LORA_Tx §
#define ResetPin 5

int message = 1000;

void setup() {

  Serial.begin(115200);
  // Write the Reset Pin high to stop reset (Its active low)
  digitalWrite(ResetPin, HIGH);


}

void loop() {

  // Sends a number and then waits 3 seconds and then sends the next number
  message++;

  String value = String(message);

  // Print the message to the serial port, ie send the data
  Serial.println("AT+SEND=2,"+String(value.length()) +","+ String(message));
  delay(3000);

}
```

Figure 9 - TX Code

The transmitter code in figure 9 shows how the transmitter will send an incrementing number to the receiver. First, the baud rate is set to match the rate of the transceiver. The reset pin is set to high because according to the datasheet, it is active low to reset the transceiver chip. The loop is simple, it increments a number and then sends that number to the serial port. It is sent using the SEND command specified in the AT commands document. This command takes three parameters, address, payload length and data. The address is specified as two because that is the address of the receiver. The length is the length of the string, and the message is the number that was incremented. Then the code is delayed three seconds and repeated with the next number.

LORA_Rx §

```
#define ResetPin 5

String message;

void setup() {

  Serial.begin(115200);
  // Write the Reset Pin high to stop reset (Its active low)
  digitalWrite(ResetPin, HIGH);

}

void loop() {

  // Receive the data and then print it to the serial monitor
  if(Serial.available())
  {
    message = Serial.readString();

    // Print message to serial
    Serial.print(message);
  }

}
```

Figure 10 - RX Code

The receiver code in figure 10 shows how the receiver will take in a signal. First, the baud rate is set to match the rate of the transceiver. The reset pin is set to high because according to the datasheet, it is active low to reset the transceiver chip. The loop is simple, it waits until there is data available in the serial port, i.e. it waits until there is a message, and then when there is, it stores that data in the message variable and then prints that data. The printed data can then be verified by looking at the serial port and seeing if the numbers are all there and in order.

4.1.3 - General Validation

The design of the data transmission block was created with several objectives in mind, including cost, availability, reliability and performance. To begin, the block requires two transceiver modules and two microcontrollers (Arduino Nano), however, these two microcontrollers will be used by other blocks as well, so they are a shared cost. The total cost for the two transceivers is $39, about ⅛ the cost of the system. This leaves room in the budget for the other blocks. Furthermore, the chosen transceiver module, REYAX RYLR896, is widely available and ships from the continental United States. This is especially important because if there is a faulty part, or a new system to be built, the required parts will have reasonable shipping times and are not nearing obsolescence.

The LORA transceiver module is extremely low power and high reliability, it can be left in the field untouched for 10 years continuously transmitting. This is an important feature of the data transmission in the system, it must be reliable without maintenance. Lastly, LORA wireless transmission technology is an emerging tool that will have excellent performance for this use case. The long range transmission method works up to 15km distance, but our unit will only be transmitting 1km. In addition, the unit will be kept in open fields without obstruction, so the signal strength and signal path will be optimal. This will allow for consistent, uninterrupted data transmission for the system. Therefore, the block will function indefinitely without the need for maintenance or monitoring.

The alternate solutions to this problem would be either Wifi, Bluetooth or cellular, however, each of these has its downfalls that make LORA the correct choice. Bluetooth does not have nearly enough range for this application. Wifi will not work either because there is no Wifi infrastructure in the agricultural fields. Cellular would be possible, but it draws significant power and comes with licensing fees, it is overkill for this application. This leaves LORA as the clear choice.

Ultimately, the design is perfectly suited for the needs of this project. The two transceivers will be able to send data the correct distance at the correct rate that is needed. They will do this while not consuming excessive power or having an excessive cost. The units chosen have all of the necessary characteristics, like extreme reliability and low maintenance. The microcontroller program is simple and will allow for verification of the block. Taking all of this into account, the block design is suited precisely for the project partner needs, along with the engineering goals of the system.

4.1.4 - Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details for this block above meet or exceed each property?**

Table 1 - Validation dt_trnsmssn_g_-_dt_dsply_comm

Baud Rate: 115,200	The default Baud Rate of the transceiver is this value.	The microcontroller will be set to match this baud rate for communication.
Logic Level - Active High	UART communication is active high.	The transceiver receives data using UART. The active high has also been verified with an oscope.
Logic Level: 3.3V	This is the logic level because the transceiver operates at 3.3V.	The receiver outputs 3.3V and the microcontroller can read that value as HIGH according to the ATmega328P Datasheet

Table 2 - Validation mcrcntrllr_dt_trnsmssn_comm

Baud Rate: 115,200	The default Baud Rate of the transceiver is this value.	The microcontroller will be set to match this baud rate for communication.
Logic Level - Active High	UART communication is active high.	The transceiver receives data using UART. The active high has also been verified with an oscope.
Logic Level: 5V	This is the logic level because the microcontroller operates at 5V.	In my design, the microcontroller outputs 5V, but there is a ⅔ voltage divider that lowers this voltage to 3.3V so that the transceiver can handle it.

Table 3 - Validation pcb_dt_trnsmssn_dcpwr (Transmitter)

Inominal: 15mA	While the transmitter is on standby, the current draw is 15mA.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.
Ipeak: 75mA	The peak current that the transmitter will draw is 43mA because it is at its peak when it is actively transmitting, 75mA leaves buffer room in case the transmitter ever needs more current, while being under the limited output of the microcontroller.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.
Vmax: 3.5V	This value was chosen because it exceeds the maximum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the maximum input voltage can be up to 3.6V. So 3.5V is within tolerance.
Vmin: 2.9V	This value was chosen because it exceeds the minimum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the minimum input voltage can be as low as 2.8V. So 3.5V is within tolerance.

Table 4 - G_-_dt_dsply_dt_trnsmssn_dcpwr (Receiver)

Inominal: 15mA	During a receive operation, the max current draw is 16.5mA, and the nominal is around 15mA.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.
Ipeak: 75mA	The peak current that the transmitter will draw is 43mA because it is at its peak when it is actively transmitting, 75mA leaves buffer room in case the transmitter ever needs more current, while being under the limited output of the microcontroller.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.
Vmax: 3.5V	This value was chosen because it exceeds the maximum ripple voltage from	This value will work because the REYAX RYLR896 Datasheet page 4 specifies

	the microcontroller.	that the maximum input voltage can be up to 3.6V. So 3.5V is within tolerance.
Vmin: 2.9V	This value was chosen because it exceeds the minimum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the minimum input voltage can be as low as 2.8V. So 3.5V is within tolerance.

4.1.5 - Verification Process

Assembly

1. The wiring will be setup according to the wiring diagram for the transmitter and the receiver
2. The transceivers will be mounted to the 8ft posts

Programming

1. Each module will be given its AT commands as specified above.
2. The transmitter module will be programmed to send an incrementing number starting from 1000 to the receiver with address 2. The number will be equivalent to sensor data values.
3. The receiver module will be programmed to receive the number and display it to the serial monitor for verification that it can receive the correct data

Verification Testing

Required Tools:

1. Digital Multimeter (DMM)
2. Oscilloscope
3. Adjustable Voltage Supply
4. Laptop

Pcb_dt_trnsmssn_dcpwr

1. The transmitter module RX will be connected to the microcontroller TX and a DC Power Supply for Vdd, GND will be common on power supply and microcontroller.
2. The power supply will be set to 2.9V.
3. The current draw will be measured using a DMM and verified at 43mA.
4. The serial output of the receiver will show that data can be transmitted at this voltage level.
5. The power supply will be set to 3.5V.
6. The current draw will be measured using a DMM and verified at 43mA.
7. The serial output of the receiver will show that data can be transmitted at this voltage level.

G_-_dt_dsply_dt_trnsmssn_dcpwr

1. The transmitter module RX will be connected to the microcontroller TX and a DC Power Supply for Vdd, GND will be common on power supply and microcontroller.

2. The power supply will be set to 2.9V.
3. The current draw will be measured using a DMM and verified at 16.5mA.
4. The serial output of the receiver will show that data can be transmitted at this voltage level.
5. The power supply will be set to 3.5V.
6. The current draw will be measured using a DMM and verified at 16.5mA.
7. The serial output of the receiver will show that data can be transmitted at this voltage level.

Mcrcntrllr_dt_trnsmssn_comm

1. The transmitter will have Vdd and GND connected to the microcontroller, and TX from the microcontroller will be connected to the oscope.
2. The oscope will display that the logic level is HIGH and that the logic level voltage is 3.3V. It will also show the baud rate.
3. The baud rate will also be verified using the serial output port on the receiver and setting it to the correct rate.

Dt_trnsmssn_g_-_dt_dsply_comm

1. The transmitter will have Vdd and GND connected to the microcontroller, and TX from the microcontroller will be connected to the oscope.
2. The oscope will display that the logic level is HIGH and that the logic level voltage is 3.3V. It will also show the baud rate.
3. The baud rate will also be verified using the serial output port on the receiver and setting it to the correct rate.

4.1.6 - References and File Links

4.1.6.1 - References

[1] M. Zachmann, “The best lora settings for range and reliability,” *Medium*, 18-Jan-2022. [Online]. Available: https://medium.com/home-wireless/testing-lora-radios-with-the-limesdr-mini-part-2-37fa481217ff. [Accessed: 19-Jan-2022].

4.4.6.2 - File Links

REYAX RYLR896 Lora Module SX1276 UART

REYAX RYLR896 Datasheet

REYAX RYLR896 AT Commands

[ATmega328P Datasheet]

4.1.7 - Revision Table

Date	Changes
1/3	Created the Document and Outline
1/4	Added Overview and Block Design
1/6	Added General Validation and Interface Table
1/7	Added the Testing Process and References, Revised all sections
1/17	Updated the overview with some context information
1/18	Added unique wiring diagrams for Transmitter and Receiver, added more context to schematics and mechanical drawings along with interface names as suggested from feedback.
1/19	Updated general validation to include a statement of why the block will work, according to peer feedback.
1/19	Added code instead of pseudocode, along with AT command information for more in-depth validation
1/20	Updated testing process to include numbered lists and interface names
1/21	Added discussion of alternative solutions to general validation
1/21	Updated properties and validations of those properties
1/21	Made final formatting adjustments

4.2 - Field PCB

4.2.1 - Description

Champion: Eric van Klaveren

The water flow monitoring system has two custom PCBs in the design, one in the field monitoring water flow, and the other in the office displaying data. The purpose of the field PCB is to house a microcontroller chip to control the water monitoring system. The PCB will hold the Arduino Nano microcontroller, but it will also house some connectors for the LORA transmitter and the pressure sensors, along with some passive components. The field PCB interfaces with 4 other blocks; it receives power from the hybrid solar power unit and has a mechanical connection to the enclosure. In addition, it communicates and supplies power to both the wireless transmitter and the pressure sensor. This PCB will be out in a field near the pressure sensor so that it can record data and then send it off to the transmitter and to the office PCB.

The PCB will be designed in EasyEDA, a custom PCB software tool. The schematics will be designed, then transferred over into PCB form, where they will be laid out and traces will be connected. Finally, the PCB will be exported as gerber files and ordered from a custom PCB manufacturer.

4.2.2 - Design

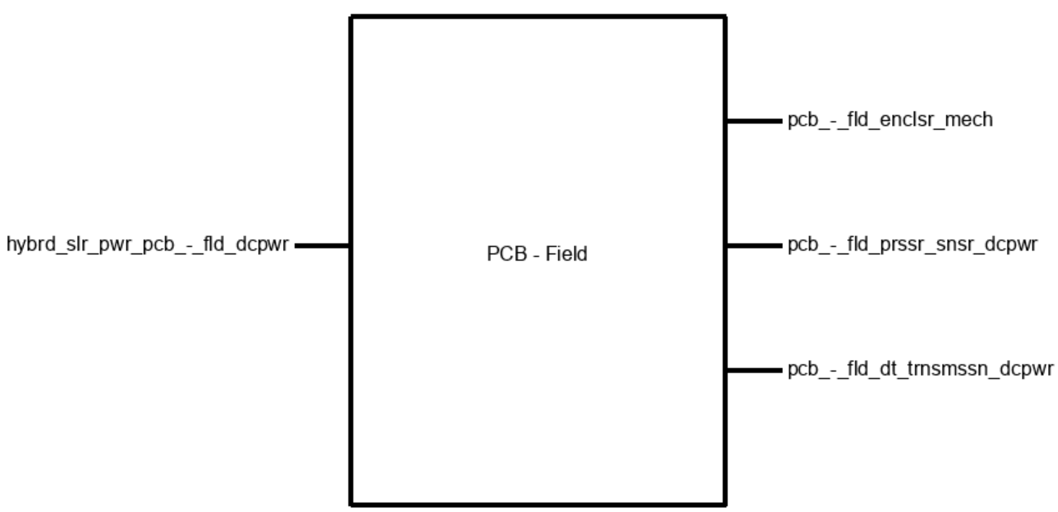


Figure 1 - Black Box Diagram - Field PCB

Hybrd_slr_pwr_pcb_-_fld_dcpwr - This is the input power from the solar panel to the microcontroller, which then distributes it to the other units.

Pcb_-_fld_enclsr_mech - This is the mechanical connection from the PCB to the enclosure.

Pcb_-_fld_prssr_snsr_dcpwr - This is the DC power from the microcontroller to the pressure sensor.

Pcb_-_fld_dt_trnsmssn_dcpwr - This is the DC power from the microcontroller to the wireless transmitter.

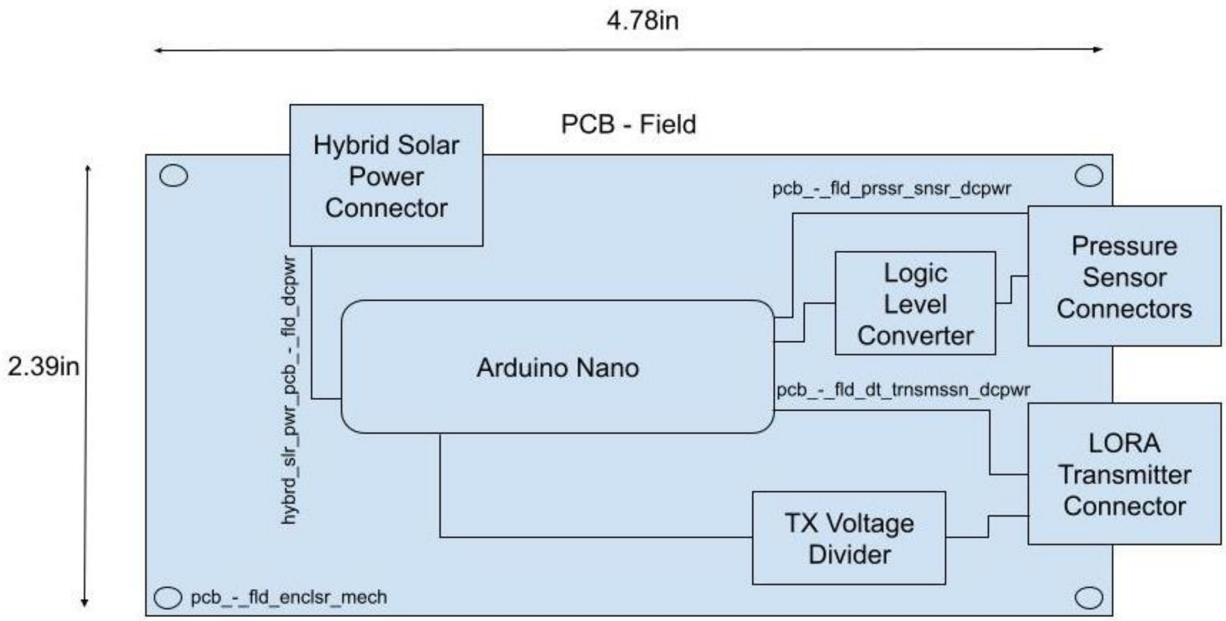


Figure 2 - Field PCB Block Diagram

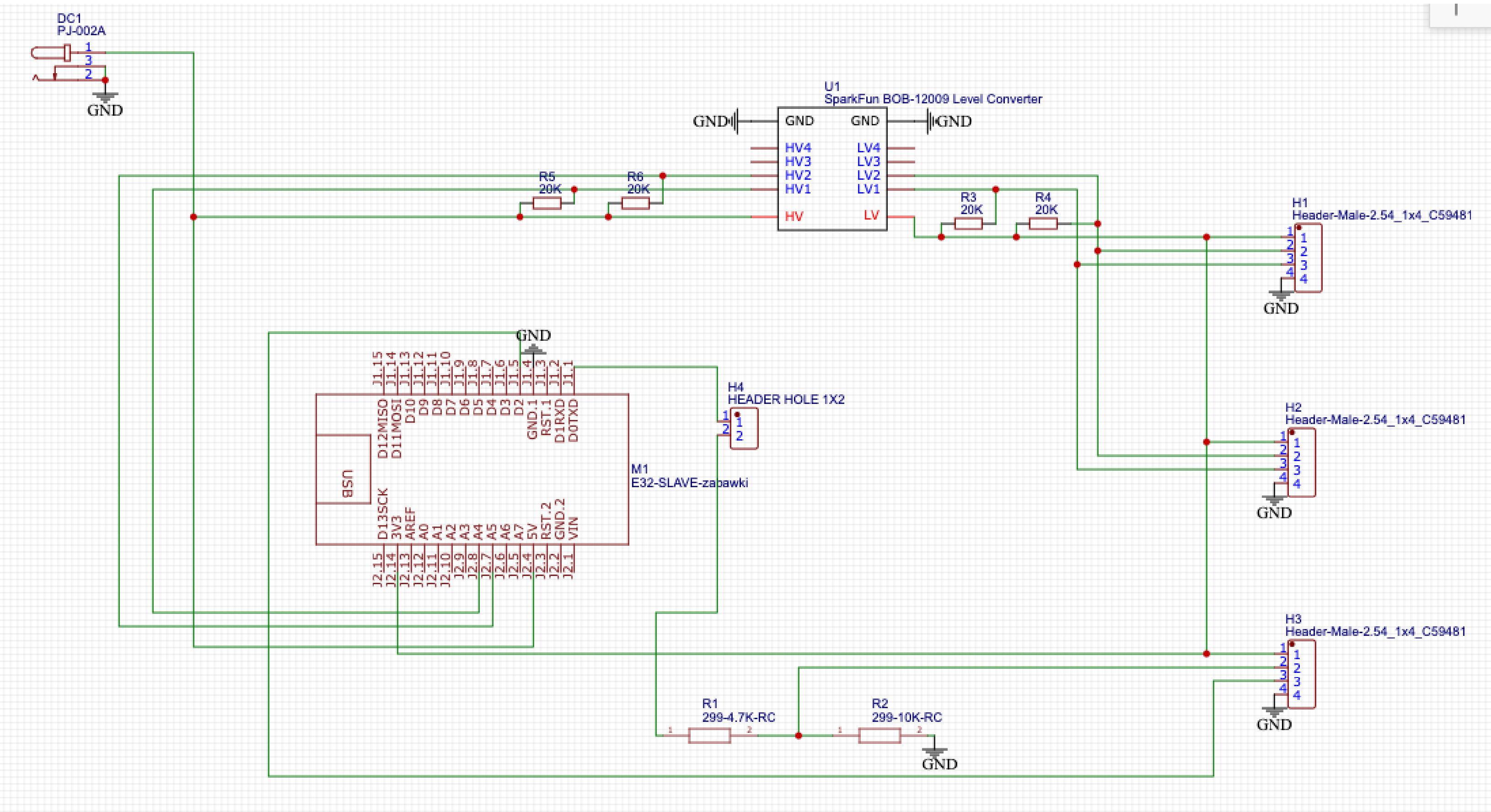


Figure 3 - Field PCB Schematic

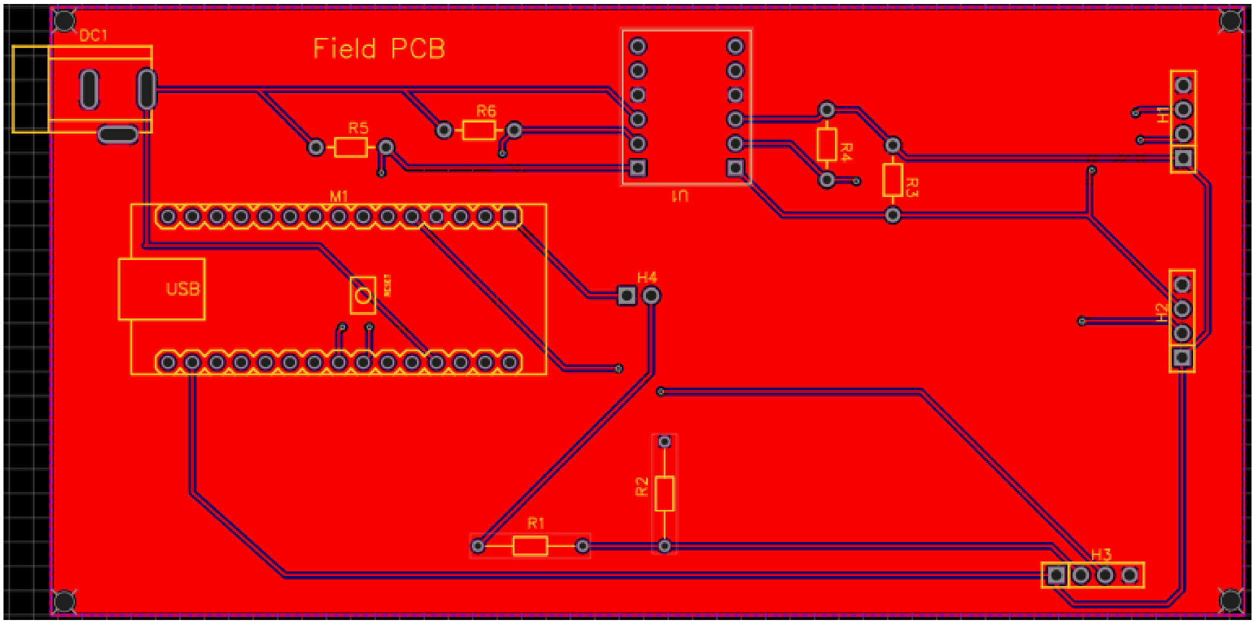


Figure 4 - Field PCB Trace Diagram

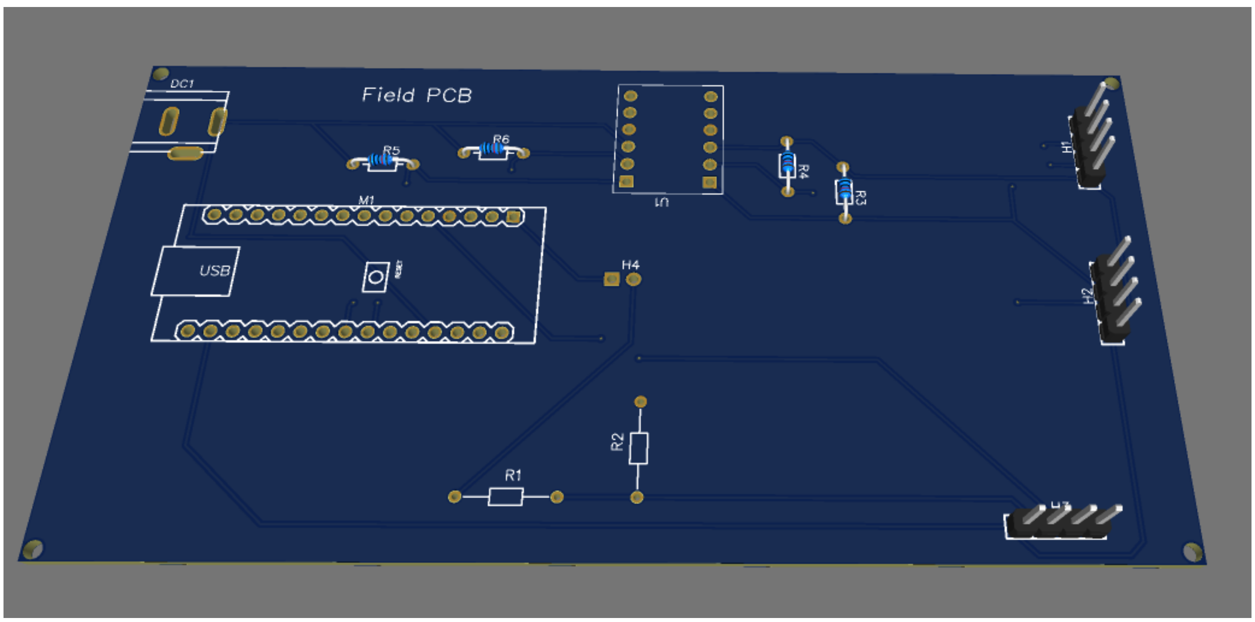


Figure 5 - Field PCB 3D Model

Figure 2 shows the block diagram for the field PCB. In the center there is an Arduino Nano microcontroller, the processor for the sensors in the field. The PCB will be mounted inside a waterproof enclosure. Figure 3 shows the schematic of the PCB. It will be receiving 5V from the hybrid solar power via a connector. The microcontroller will also supply power to the pressure sensors and the LORA transmitter, and it will send sensor data to the transmitter that needs to be transmitted. The pressure sensors operate at 3.3V, whereas the microcontroller operates at

5V, so a logic level converter will be placed in between communication lines to avoid sending too much or too little power to the sensors. The converter to be used will be the Sparkfun BOB-12009. This device allows for 5V devices to seamlessly interact with 3.3V devices and vice-versa. This was an essential component for the PCB in order to allow for the microcontroller to communicate with the pressure sensors. The voltage divider is there to ensure that the TX communication to the LORA chip does not exceed 3.5V for the same reason. There is also a 2 pin header connection that interrupts the TX connection, this is because the TX/RX pins on the Arduino must be disconnected when programming the device, so the jumper can be removed for programming, and then subsequently replaced to reconnect TX.The pressure sensor and LORA chip will have connectors so that they can easily be plugged into the PCB and connect to the microcontroller. Figure 4 shows the trace diagram of the completed board. It has 4 mounting points on the corner to allow it to be mounted securely in the enclosure. The overall size of the board is about 2.4 inches by 4.8 inches. The trace widths will be 20 mils with 1 oz/ft^2 copper wieght to ensure the maximum current can be handled. Lastly, figure 5 shows a 3D render of the completed PCB, without the components mounted onto it.

4.2.3 - General Validation

The goal of the PCB is to be a single piece of hardware that holds all the necessary connections and interfaces for the microcontroller. Each PCB, field and office, are processors with connections to facilitate the interactions with other blocks. A PCB with soldered components is a permanent, reliable piece of hardware that will not fall apart with time when designed correctly. The field PCB needs to be a plug and play device that can stay enclosed in the field for weeks, months or even years with no maintenance. The office PCB will do the same: receive data and process it indefinitely. The goal of the final device is to be a no maintenance plug and play system, and for that a PCB with permanently mounted components is necessary.

The cost of the PCBs will be about $30 each including all components, so $60 total. This is about ⅕ of the total budget, but it is a significant portion of the project. The processors are the most expensive pieces and they are the core of the system and control several other blocks, therefore this price is certainly within range for the project budget. The PCBs will be purchased from OSHPark, an Oregon based PCB manufacturer, in order to ensure premium quality and avoid international shipping costs/time. All of the components being used, the microcontroller, the connectors and the passive components are widely available and nowhere close to end-of-life. The total time to order a PCB and receive/assemble it will be 10 days maximum, leaving plenty of time in the project timeline for changes or even a redo if absolutely necessary. The PCB will use connectors for the devices it interacts with, likely molex connectors that connect to the outside of the enclosure, where another waterproof connector can be used to connect to the sensors and transceivers, along with the power. The sizes of each PCB are large enough to allow plenty of room for the device and connectors, and small enough to fit in the enclosure without issue. The trace widths will be 20 mils at 1oz/ft^2 copper weight to allow for adequate current to all parts of the PCB.

Alternate solutions to house the microcontroller and connectors would be a breadboard or a protoboard. Breadboards are readily available and can house the microcontroller and connect to other devices without issue, but they are not a permanent solution. Connections are not soldered in and will not remain reliable for years without needed maintenance or fixes. Protoboards also can certainly serve the same purpose, but the use of a PCB is easier, more professional, and higher quality. Protoboards require extensive soldering and testing time, whereas a PCB is professionally manufactured and tested, reducing the human error component.

With all of these things considered, the use of a PCB is the clear choice. The project partners' needs are a plug and play system that will last without maintenance, and a PCB suits those needs. Using the discussed design, the PCB will have adequate current supply and solid connections, and the cost and timeline are well within budget. This design fits all of the necessary characteristics and exceeds the performance of any alternatives. Ultimately, this design fits the needs of the project partner and exceeds all of the necessary engineering requirements.

4.2.4 - Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each

		property?

Table 1 - hybrd_slr_pwr_pcb_-_fld_dcpwr

Inominal: 50mA	This nominal current was chosen based on the expected current needs of the system overall.	The RYLR896 IC package that runs the LORA communication module has the highest current draw while transmitting at 43 mA. This will be a routine task performed by the LORA module. The ATmega328P microcontroller has an active current draw of 1.5 mA at 3.3V, while the MS5803-14BA bar module has a typical supply current of 12.5 µA at 1 sample per second. Adding contingency for non-ideal internal losses, rounding up to 50 mA as a nominal current at 5V is a realistic expected nominal current load. Battery Charging IC Datasheet
Ipeak: 100mA	In this example, we don't expect the current draw of the whole system to ever spike above this number. The value was selected by adding up the maximum current of all parts and multiplying by 2	The MS5803-14BA bar module has a peak supply current during ADC conversion of 1.4 mA, while the maximum current for the Atmega328P is 14 mA, and the LORA module maintains the same 43 mA. Taking the Inominal and multiplying it by two gives the system more than enough headroom. Realistically the system could never draw this much current factoring in each components’ maximum current ratings. ATmega328P Datasheet
Vmax: 4.2V	In this example, this property was chosen based on the electrical characteristics of the 18650 Lithium-ion cell	While 18650 Lithium-ion cells have a nominal voltage of 3.7V, they can hold a max charge of 4.2V. Even at

	used for energy storage.	Vmax, this voltage can run the ATmega328P directly with no conversion, and be stepped down to 3.3V which will be used as the Vcc for system devices.
Vmin: 3.0V	In this example, this property was chosen based on the highest minimum operating voltages of the system devices.	While the Atmega328P can operate with as low as 2.5V of source voltage, both the bar module and LORA communication module require a minimum of 3V for operation.

Table 2 - pcb_-_fld_enclsr_mech

Fasteners: M4 Bolts	M4 bolts are strong enough to securely fasten a PCB.	The M4 bolts are strong enough to hold the PCB in place during shocks to the enclosure like a drop.
Length - 4.78in	This is slightly under the length of the board, so that the holes are not off the board and have enough board to fasten too.	The length was decided based on the size of the components used, and the length for the fastener holes needs to be slightly under that.
Height - 2.39in	This is slightly under the height of the board, so that the holes are not off the board and have enough board to fasten too.	The height was decided based on the size of the components used, and the length for the fastener holes needs to be slightly under that.

Table 3 - pcb_-_fld_prssr_snsr_dcpwr

Inominal: 7 µA	This value was chosen based on the sum of values given in the MS5803 pressure sensor datasheet [1]. As well as the BMP180 barometric pressure sensor datasheet [2]	From the Standby supply current value in the Electrical Characteristics table, Pg.2, in the MS5803 pressure sensor datasheet [1] As well as the Standby current value in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2] Pressure Sensor Datasheet
Ipeak: 35 uA	This is the maximum possible current for the pressure sensor.	This was done by multiplying the nominal current by 5.
Vmax: 3.6 V	This value was chosen based on the values given in the MS5803 pressure sensor datasheet [1]. As well as the BMP180 barometric pressure sensor datasheet [2]	From the Operating Supply voltage value in the Electrical Characteristics table, Pg.2, in the MS5803 pressure sensor datasheet [1]. As well as the Supply voltage value in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2]
Vmin: 1.8 V	This value was chosen based on the values given in the MS5803 pressure sensor datasheet [1.]As well as the BMP180 barometric pressure sensor datasheet [2]	From the Operating Supply voltage value in the Electrical Characteristics table, Pg.2, in the MS5803 pressure sensor datasheet [1] As well as the Supply voltage value in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2]

Table 4 - pcb_-_fld_dt_trnsmssn_dcpwr

Inominal: 15mA	While the transmitter is on standby, the current draw is 15mA.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.
Ipeak: 75mA	The peak current that the transmitter will draw is 43mA because it is at its peak when	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it

	it is actively transmitting, 75mA leaves buffer room in case the transmitter ever needs more current, while being under the limited output of the microcontroller.	has been verified by a DMM.
Vmax: 3.5V	This value was chosen because it exceeds the maximum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the maximum input voltage can be up to 3.6V. So 3.5V is within tolerance.
Vmin: 2.9V	This value was chosen because it exceeds the minimum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the minimum input voltage can be as low as 2.8V. So 3.5V is within tolerance.

4.2.5 - Verification Process

Required Testing Tools

1. Digital Multimeter
2. Oscilloscope
3. Variable DC Power Supply
4. Ruler
5. Laptop

Assembly

1. Solder Microcontroller to PCB.
2. Solder the four connectors to PCB: Power, LORA and 2 Pressure Sensors.

Verification Testing

Hybrd_slr_pwr_pcb_-_fld_dcpwr

1. Show that the system can work at 3V and 4.2V by plugging in a variable power supply to the power and ground and show the system functioning.
2. Show that the draw never exceeds 100mA on the power supply while powering both pressure sensors and the transmitter.

Pcb_-_fld_enclsr_mech

1. Show the m4 bolts mounted at the correct measurements by measuring each of the mounting holes on the board with a ruler and making sure they are 4.78 and 2.39 inches apart respectively.

Pcb_-_fld_prssr_snsr_dcpwr

1. Show that the system can supply 35uA by setting a current draw of 35uA on the variable power supply.
2. Show that the system's voltage is within 1.8 - 3.6V by attaching a DMM to the 3.3V power pin and verifying that it is within 1.8V to 3.6V at all times.

Pcb_-_fld_dt_trnsmssn_dcpwr

1. Show that the system can supply 75mA by setting the variable power supply to draw 75mA and showing that the system can meet that draw.
2. Show that the system can supply between 2.9 and 3.5V by attaching the DMM to the power pin and verifying that the output voltage is between 2.9 and 3.5V.

This verification process was completed and the block passed all interfaces and properties.

4.2.6 - References and File Links

4.1.6.1 - References

[1] "MS5803-14BA miniature 14 bar module," Sparkfun Electronics, 07-Sep-2012. [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Weather/ms5803_14ba.pdf.

[2] "BMP180 digital pressure sensor -," Adafruit, 05-Apr-2013. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/BST-BMP180-DS000-09.pdf.

4.4.6.2 - File Links

REYAX RYLR896 Lora Module SX1276 UART

REYAX RYLR896 Datasheet

REYAX RYLR896 AT Commands

ATmega328P Datasheet

Battery Charging IC Datasheet

Pressure Sensor Datasheet

Sparkfun BOB-12009 Datasheet

4.2.7 - Revision Table

Date	Changes
2/2	Created the Document and Outline
2/2	Added overview and black box diagrams with interface description
2/3	Added all interfaces and property descriptions
2/4	Created verification plan, described the general block validation
2/4	Final formatting updates
2/13	Added how the PCBs were created and general clarifications according to peer feedback
2/13	Added schematic, trace diagram, and 3D models
2/14	Added more specific details to verification plan according to peer feedback
2/16	Updated interface property descriptions and added datasheets according to peer feedback
2/18	Updated block diagrams for more accurate representation of the PCB
2/18	Final formatting and design updates

4.2 - Office PCB

4.3.1 - Description

Champion: Eric van Klaveren

The office PCB will serve a very similar purpose to the field PCB. It will house an Arduino Nano microcontroller, and it will have a connector to the wireless receiver and an area for the micro-USB cable to be plugged into the Arduino for data display. This PCB will be located in an office where water managers monitor flow data. It will house a device that will be plugged into a computer in order to show the received sensor data.

The PCB will be designed in EasyEDA, a custom PCB software tool. The schematics will be designed, then transferred over into PCB form, where they will be laid out and traces will be connected. Finally, the PCB will be exported as gerber files and ordered from a custom PCB manufacturer.

4.3.2 - Design

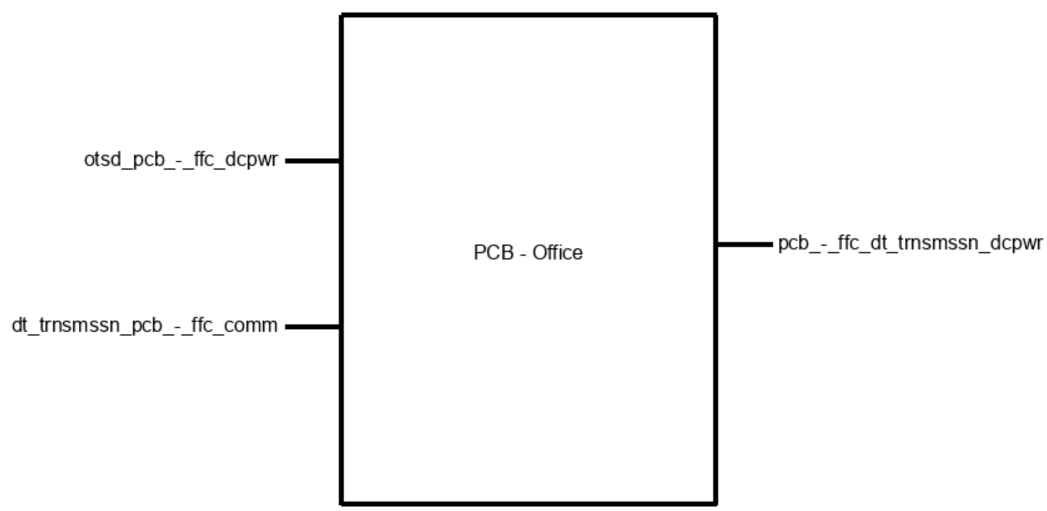


Figure 6 - Black Box Diagram - Office PCB

Dt_trnsmssn_pcb_-_ffc_comm - This is the data that is being received from the wireless unit.

Pcb_-_ffc_dt_trnsmssn_dcpwr - This is the DC power for the receiver.

Otsd_pcb_-_ffc_dcpwr - This is the input power for the Arduino from a USB port.

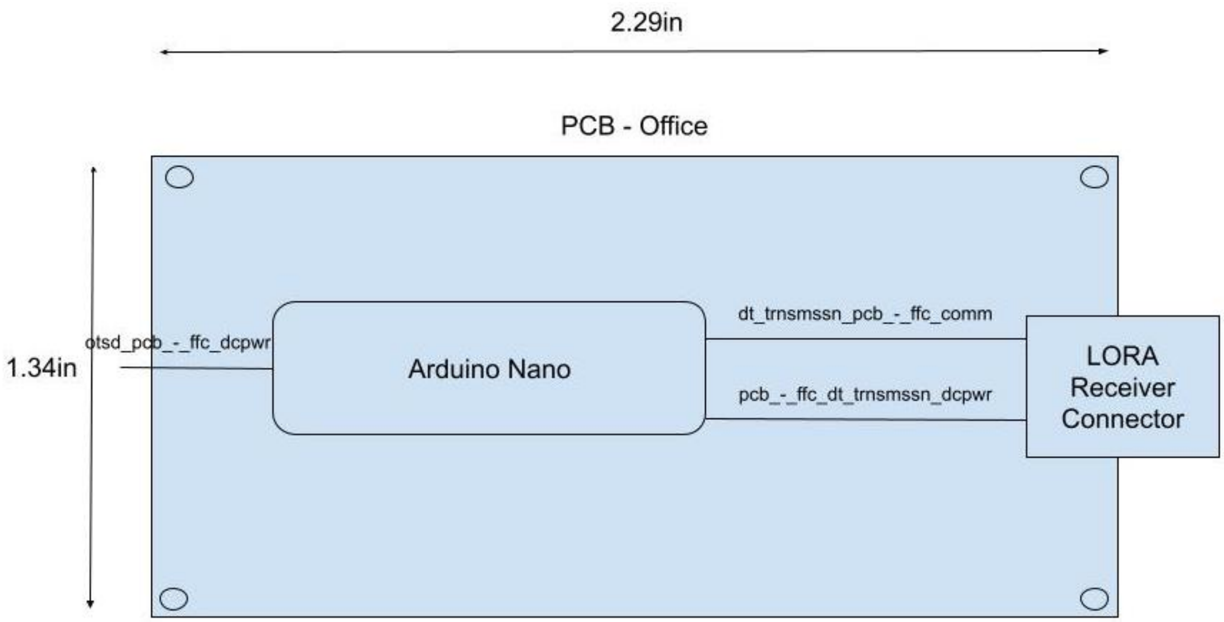


Figure 7 - Office PCB Block Diagram

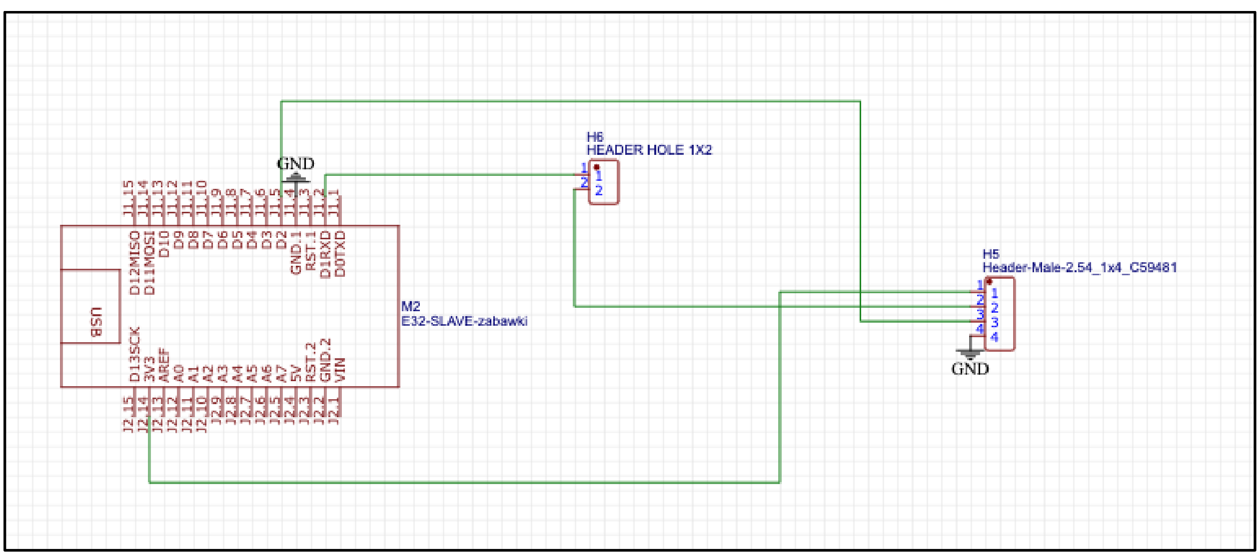


Figure 8 - Office PCB Schematic

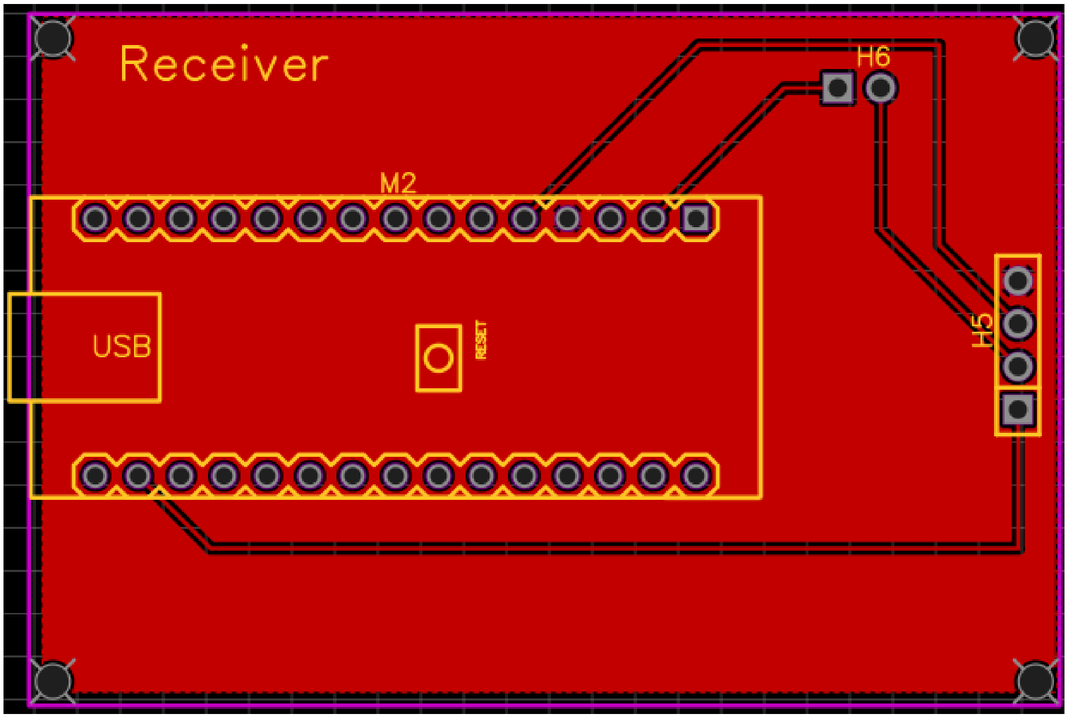


Figure 9 - Office PCB Trace Diagram

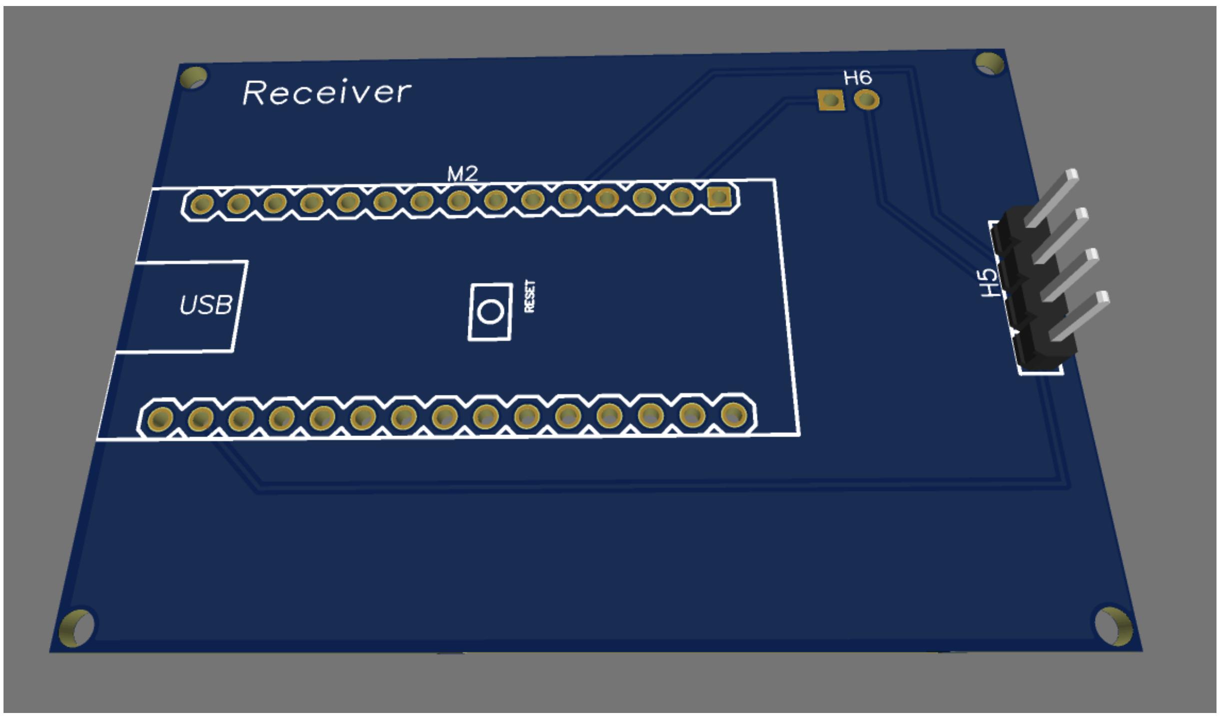


Figure 10 - Office PCB 3D Model

Figure 7 shows the block diagram for the office PCB. Similar to the field PCB, it holds an Arduino Nano microcontroller in the center. The device will be responsible for receiving sensor data and performing calculations on it to find flow rate. The schematic in figure 8 shows that it receives power from the 5V USB port on the Arduino, and it sends that power to the LORA receiver and takes in the raw sensor data that is received from the transmitter. There is a 2 pin header interrupting the RX line that can be reconnected with a jumper. This is due to the fact that the microcontroller cannot be programmed while the TX or RX lines are connected. The trace diagram in figure 9 shows the 4 mounting holes on the corners so that it can be mounted in an enclosure. The overall size is 1.3 x 2.3 inches. Lastly, figure 10 shows a 3D render of the board without the microcontroller attached.

4.3.3 - General Validation

The goal of the PCB is to be a single piece of hardware that holds all the necessary connections and interfaces for the microcontroller. Each PCB, field and office, are processors with connections to facilitate the interactions with other blocks. A PCB with soldered components is a permanent, reliable piece of hardware that will not fall apart with time when designed correctly. The field PCB needs to be a plug and play device that can stay enclosed in the field for weeks, months or even years with no maintenance. The office PCB will do the same: receive data and process it indefinitely. The goal of the final device is to be a no maintenance plug and play system, and for that a PCB with permanently mounted components is necessary.

The cost of the PCBs will be about $30 each including all components, so $60 total. This is about ⅕ of the total budget, but it is a significant portion of the project. The processors are the most expensive pieces and they are the core of the system and control several other blocks, therefore this price is certainly within range for the project budget. The PCBs will be purchased from OSHPark, an Oregon based PCB manufacturer, in order to ensure premium quality and avoid international shipping costs/time. All of the components being used, the microcontroller, the connectors and the passive components are widely available and nowhere close to end-of-life. The total time to order a PCB and receive/assemble it will be 10 days maximum, leaving plenty of time in the project timeline for changes or even a redo if absolutely necessary. The PCB will use connectors for the devices it interacts with, likely molex connectors that connect to the outside of the enclosure, where another waterproof connector can be used to connect to the sensors and transceivers, along with the power. The sizes of each PCB are large enough to allow plenty of room for the device and connectors, and small enough to fit in the enclosure without issue. The trace widths will be 20 mils at 1oz/ft^2 copper weight to allow for adequate current to all parts of the PCB.

Alternate solutions to house the microcontroller and connectors would be a breadboard or a protoboard. Breadboards are readily available and can house the microcontroller and connect to other devices without issue, but they are not a permanent solution. Connections are not soldered in and will not remain reliable for years without needed maintenance or fixes. Protoboards also can certainly serve the same purpose, but the use of a PCB is easier, more professional, and higher quality. Protoboards require extensive soldering and testing time, whereas a PCB is professionally manufactured and tested, reducing the human error component.

With all of these things considered, the use of a PCB is the clear choice. The project partners' needs are a plug and play system that will last without maintenance, and a PCB suits those needs. Using the discussed design, the PCB will have adequate current supply and solid connections, and the cost and timeline are well within budget. This design fits all of the necessary characteristics and exceeds the performance of any alternatives. Ultimately, this design fits the needs of the project partner and exceeds all of the necessary engineering requirements.

4.3.4 - Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details for this block above meet or exceed each property?**

Table 5 - dt_trnsmssn_pcb_-_ffc_comm

Datarate: Baud Rate: 115,200	The default Baud Rate of the transceiver is this value.	The microcontroller will be set to match this baud rate for communication.
Other: Logic Level: 3.3V	UART communication is active high.	The transceiver receives data using UART. The active high has also been verified with an oscope.
Other: Logic Level: Active High	This is the logic level because the transceiver operates at 3.3V.	The receiver outputs 3.3V and the microcontroller can read that value as HIGH according to the ATmega328P Datasheet

Table 6 - pcb_-_ffc_dt_trnsmssn_dcpwr

Inominal: 15mA	During a receive operation, the max current draw is 16.5mA, and the nominal is around 15mA.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.

Ipeak: 75mA	The peak current that the transmitter will draw is 43mA because it is at its peak when it is actively transmitting, 75mA leaves buffer room in case the transmitter ever needs more current, while being under the limited output of the microcontroller.	The REYAX RYLR896 Datasheet page 4 specifies this current draw level, and it has been verified by a DMM.
Vmax: 3.5V	This value was chosen because it exceeds the maximum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the maximum input voltage can be up to 3.6V. So 3.5V is within tolerance.
Vmin: 2.9V	This value was chosen because it exceeds the minimum ripple voltage from the microcontroller.	This value will work because the REYAX RYLR896 Datasheet page 4 specifies that the minimum input voltage can be as low as 2.8V. So 3.5V is within tolerance.

Table 7 - otsd_pcb_-_ffc_dcpwr

Inominal: 100mA	This is the current draw of the Arduino with the receiver.	The Arduino can handle 100mA. ATmega328P Datasheet
Ipeak: 500mA	This is the maximum current draw from a USB port.	The Arduino will not draw above its rated current.
Vmin: 4.9V	This is the minimum voltage from a USB port with a 200mV voltage ripple.	The Arduino Nano can function from 4.8 to 5.2V, which is within the bounds of the ripple.
Vmax: 5.1V	This is the maximum voltage from a USB port with a 200mV voltage ripple.	The Arduino Nano can function from 4.8 to 5.2V, which is within the bounds of the ripple.

4.3.5 - Verification Process

Required Testing Tools

6. Digital Multimeter
7. Oscilloscope
8. Variable DC Power Supply
9. Ruler
10. Laptop

Assembly

1. Solder the Microcontroller to the PCB.
2. Solder the LORA connector to the PCB.

Verification Testing

Dt_trnsmssn_pcb_-_ffc_comm

1. Show that the system can support a baud rate of 115,200 by showing the Arduino IDE serial monitor receiving data with the baud rate set at 115,200.
2. Show that the system is 3.3V and active high by attaching the RX pin to an oscilloscope and showing that the signal is at 3.3V and active high.

Pcb_-_ffc_dt_trnsmssn_dcpwr

1. Show that the system can supply 75mA by setting the variable power supply to draw 75mA and showing that the system can meet that draw.
2. Show that the system can supply between 2.9 and 3.5V by attaching the DMM to the power pin and verifying that the output voltage is between 2.9 and 3.5V.

Otsd_pcb_-_ffc_dcpwr

1. Show that the system does not draw more than 500mA by attaching a power supply to the power pin and setting the device to receive data. Then verify that the draw on the power supply is less than 500mA.
2. Show that the system can operate at 4.9 - 5.1V by setting the power supply to 4.9 and 5.1V on power and ground of the Arduino Nano.

G_-_prgrmmbl_npt_mcrcntrllr_usrin

1.show the interface have the length, width and height

2. Show that the user interface have the options of loading data and plotting data

G_-_dt_dsply_otsd_usrout

1.shows the graph of water level
2:Data at least 24 months

4.3.6 - References and File Links

4.1.6.1 - References

[1] “MS5803-14BA miniature 14 bar module,” Sparkfun Electronics, 07-Sep-2012. [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Weather/ms5803_14ba.pdf.

[2] “BMP180 digital pressure sensor -,” Adafruit, 05-Apr-2013. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/BST-BMP180-DS000-09.pdf.

4.4.6.2 - File Links

REYAX RYLR896 Lora Module SX1276 UART

REYAX RYLR896 Datasheet

REYAX RYLR896 AT Commands

ATmega328P Datasheet

Battery Charging IC Datasheet

Pressure Sensor Datasheet

Sparkfun BOB-12009 Datasheet

4.3.7 - Revision Table

Date	Changes
2/2	Created the Document and Outline
2/2	Added overview and black box diagrams with interface description
2/3	Added all interfaces and property descriptions
2/4	Created verification plan, described the general block validation
2/4	Final formatting updates
2/13	Added how the PCBs were created and general clarifications according to peer feedback
2/13	Added schematic, trace diagram, and 3D models
2/14	Added more specific details to verification plan according to peer feedback
2/16	Updated interface property descriptions and added datasheets according to peer feedback
2/18	Updated block diagrams for more accurate representation of the PCB
2/18	Final formatting and design updates

4.3 Power Supply

4.3.1 Block Overview:

The power delivery to the system will consist of a hybrid solar battery system. This hybrid system has two primary components.The first is the solar source and the second is the power management and distribution. It begins with a 5V 3.5W solar panel. This will give us a theoretical input current of 0.7A at peak sunlight conditions. This 5V output of the solar panel will be connected to the battery charging/discharging management module. This is the custom designed component of the block. It is a PCB that is centered around the TP4056 IC, which is a Lithium-ion specific charging IC.

This module allows for simultaneous passthrough power and battery charging. While there is enough sun to source solar energy, the produced voltage will be distributed through the IC to the Arduino and field devices, as well as the 18650 lithium batteries for storage. The intent of this system is to incorporate enough mAh of storage to where the system can be self-sufficient off of solar alone. This capacity will be determined through various stress testing. Integrated into the circuit will be a battery bay where different capacities can be switched easily to accommodate various run times. When there are not appropriate conditions for solar power to be generated, the IC will allow for the batteries to discharge and provide power to the devices. This combination of buck converter and battery charging IC will interface with the enclosure PCB in order to distribute various voltages throughout the system.

4.3.2 Block Design:

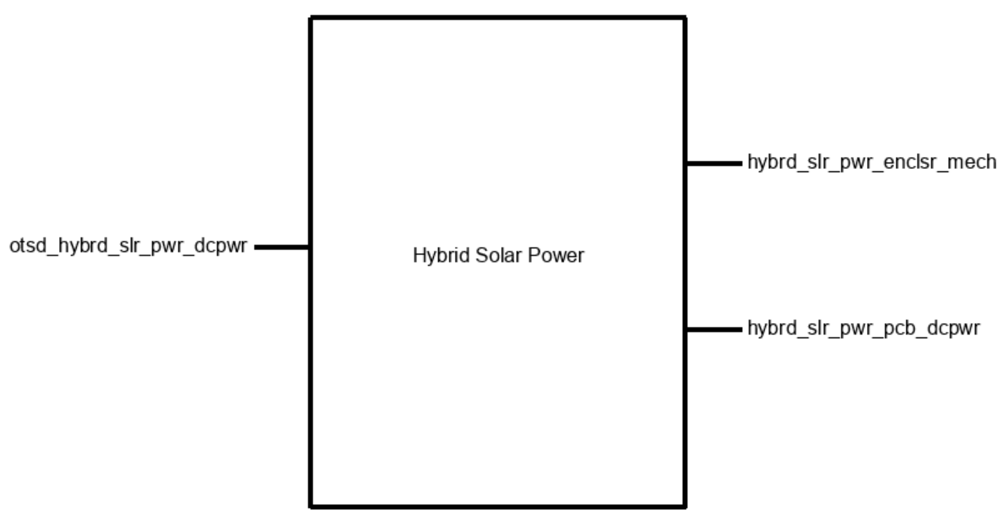


Figure 9: Black Box Diagram for Power Supply Block

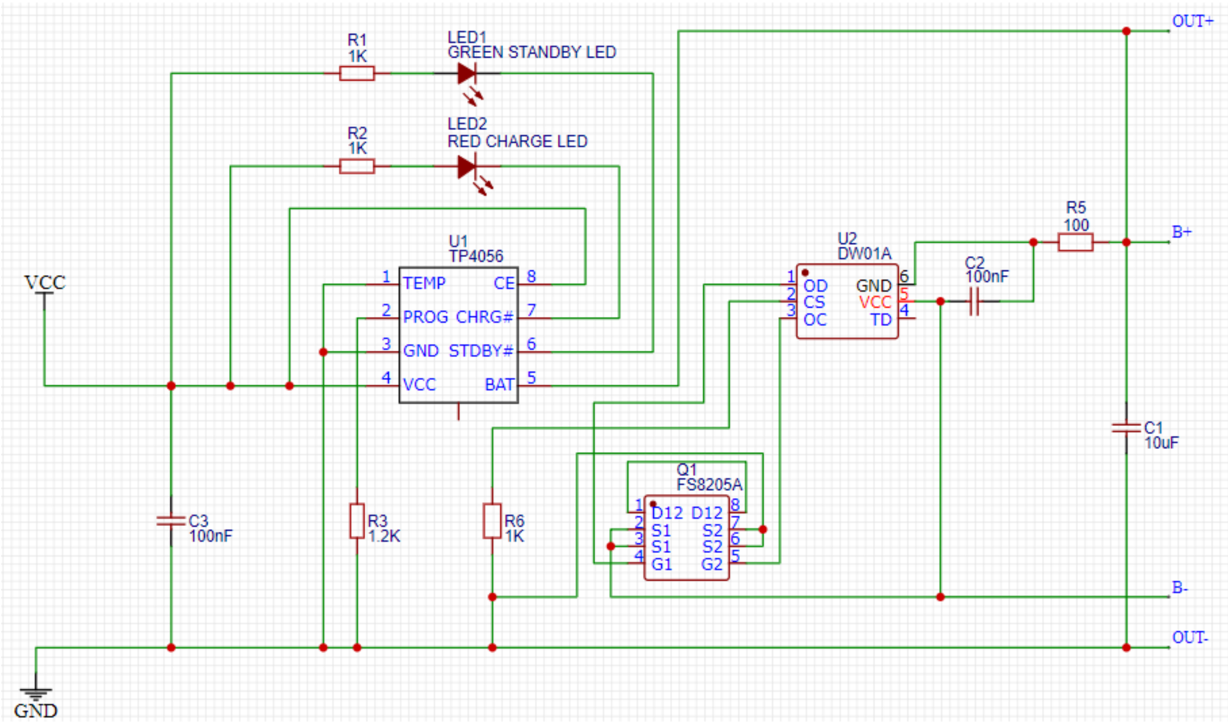


FIgure 10: Battery Charge/Discharge Module Schematic

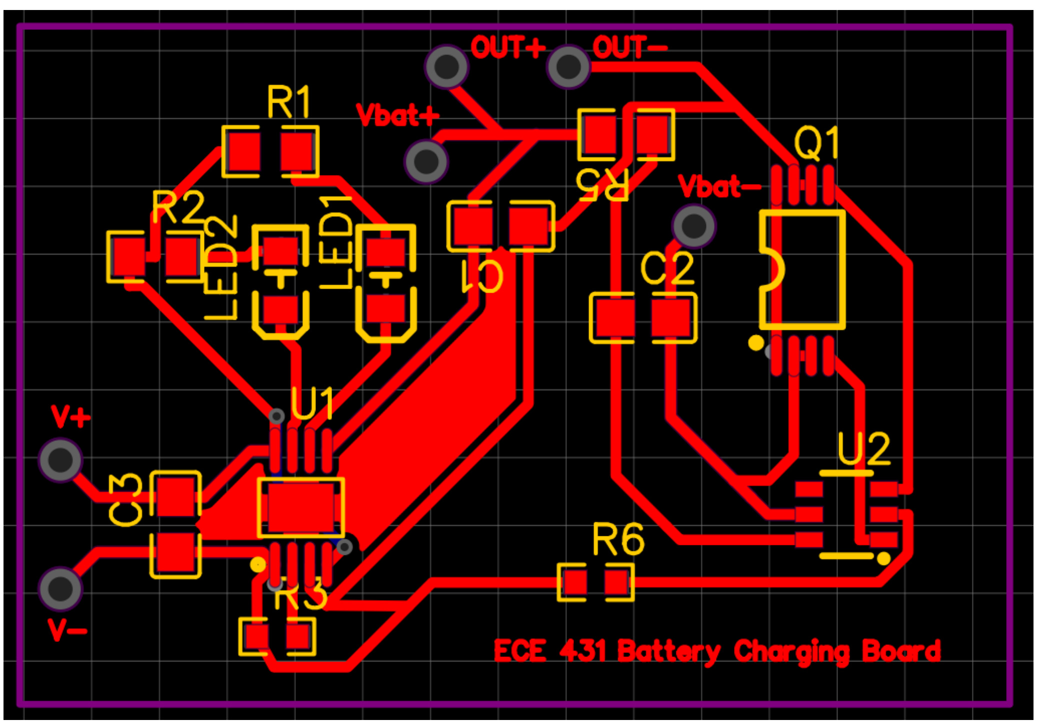


FIgure 11: Battery Charge/Discharge Module Gerber File

4.3.3 General Validation

A 3.5W solar panel was chosen for this design, as it is relatively affordable compared to higher power panels, and can provide ample source current to the buck converter. As the system consists of signal level currents, and not requiring larger amounts of power to generate heat, light, mechanical power, etcetera, a 700mA peak input current is plenty for the power demands of the system. This specific solar panel is designed for outdoor applications, and is ruggedized to IP68 standards. It also comes with an integrated mounting bracket for ease of installation for the end user.

While it would have been much more economical to use a pre-purchased battery charging module in the final design, in order to meet the requirements of the block, a custom PCB was designed for this module. The TP4056 was chosen as an affordable and readily available option for the battery charging IC. Capable of outputting 5V at 1A, it is more than sufficient for the system requirements. Referencing the datasheet for the TP4056, looking at the electrical characteristics table on page 2, 5V was specified as the typical Vcc. With the TP4056 being able to operate at an input voltage of 4V to 8V, this gives us sufficient tolerance should there be a notable voltage ripple (the design is not intended to produce a +/- 20 percent voltage ripple, however this is a additional safeguard of choosing 5V as the operating voltage).

Noting some difficulties with the original design of the buck converter having notable voltage drop at higher current draw, copper fill will be used in certain connections to provide a low resistance path to avoid such voltage drops. An additional reason 5V was chosen, is that many microcontrollers can run on 5V, including the vast majority of Atmega chips. For the 3.3V devices, it can easily be stepped down from 5V.

4.2.4 Block Validation

Table 8: Interface Properties for otsd_hybrd_slr_pwr_dcpwr

otsd_hybrd_slr_pwr_dcpwr

Interface Property	**Why is this interface this value?**	**Why do you know that your design details <u>for this block</u> above meet or exceed each property?**
Inominal: 130mA	This nominal current was chosen based on the expected current needs of the system overall	Referring to the datasheet of the TP4056 Battery Charging IC, the nominal trickle charge current for the lithium-ion battery is 130mA at 5V, which will be supplied by the output of the solar panel. Therefore we can expect approximately 130mA of current draw at the supply voltage of 5V when the battery is charging.
Ipeak: 500mA	In this example, we don't expect the current draw of the whole system to ever spike above this number. This was chosen due to a physical hardware limitation of TP4056.	While there should never be a scenario where the system draws this much current, the max charge mode current of the TP4056 was chosen. The max charge mode current hte IC can handle is 500mA at 5V, meaning the source only needs to supply 500mA at peak load.This is reasonable for our solar source, that can supply 700mA under peak load.
Nominal: 5V	In this example, this property was chosen based on the electrical characteristics of the solar panel.	The voltage that will source the battery charging module is 5V from the solar panel..
Vmin: 4.2V	In this example, this property was chosen based on the operating characteristics of the Battery Charging IC..	The TP4056 Battery Charging IC requires a minimum Vcc of 4V to operate. This falls within the operating parameters of the specified ICs, and is more than reasonable for the selected solar panel. Some additional room for voltage ripple was added onto the

		minimum 4V as a precautionary measure.

Table 9: Interface Properties for hybrd_slr_pwr_pcb_dcpwr

hybrd_slr_pwr_pcb_dcpwr

Inominal: 50mA	This nominal current was chosen based on the expected current needs of the system overall.	The RYLR896 IC package that runs the LORA communication module has the highest current draw while transmitting at 43 mA. This will be a routine task performed by the LORA module. The ATmega328P microcontroller has an active current draw of 1.5 mA at 3.3V, while the MS5803-14BA bar module has a typical supply current of 12.5 µA at 1 sample per second. Adding contingency for non-ideal internal losses, rounding up to 50 mA as a nominal current at 5V is a realistic expected nominal current load.
Ipeak: 100mA	In this example, we don't expect the current draw of the whole system to ever spike above this number. The value was selected by adding up the maximum current of all parts and multiplying by 2	The MS5803-14BA bar module has a peak supply current during ADC conversion of 1.4 mA, while the maximum current for the Atmega328P is 14 mA, and the LORA module maintains the same 43 mA. Taking the Inominal and multiplying it by two gives the system more than enough headroom. Realistically the system could never draw this much current factoring in each components' maximum current ratings.

Vmin: 3V	In this example, this property was chosen based on the highest minimum operating voltages of the system devices.	While the Atmega328P can operate with as low as 2.5V of source voltage, both the bar module and LORA communication module require a minimum of 3V for operation.
Vmax: 4.2V	In this example, this property was chosen based on the electrical characteristics of the 18650 Lithium-ion cell used for energy storage.	While 18650 Lithium-ion cells have a nominal voltage of 3.7V, they can hold a max charge of 4.2V. Even at Vmax, this voltage can run the ATmega328P directly with no conversion, and be stepped down to 3.3V which will be used as the Vcc for system devices.

Table 10: Interface Properties for hybrd_slr_pwr_enclsr_mech

hybrd_slr_pwr_enclsr_mech

Fasteners: Standoffs	Standoffs were chosen as the method of fastening for ease of use and security.	A solid base with standoffs can be designed and installed into the interior of the enclosure, adhered to the back panel. There will be holes implemented into the PCB in order to fasten the components to the back panel of the box. This allows for parts to be removed with the use of standoff screws, while solidly attaching components to the enclosure.
Fasters: Screw	Screws were chosen for the solar panel installation for convenience.	The solar panel chosen for this design includes mounting hardware in order to fasten the solar panel to a wooden post.

Passthrough: M-13	M-13 connectors were chosen for their ease of use and ability to maintain element resistant properties.	M-13 connectors will be used to connect external devices, in this case the solar panel, to the internal hardware. These are easily sourceable in gasketed versions to maintain IP67 resistance. These also allow for quick connection/disconnection so external devices can be removed from the enclosure.

4.3.5 Verification Process

In order to verify the properties of otsd_hybrd_slr_pwr_dcpwr:

1. Take the solar panel outdoors and point the panel directly towards the sunlight.
2. Using a multimeter set to current sense mode, connect the positive lead to the positive pin of the solar panel, and negative lead to the negative pin of the solar panel.
3. Ensure that the output current maintains at or above 130mA.
4. Switch the positive lead on the multimeter to the voltage input terminal on the multimeter.
5. Measure voltage at output of solar panel. Ensure that it is at least 4.2V, the required voltage of the TP4056.

In order to verify the properties of hybrd_slr_pwr_pcb_dcpwr:

6. Attach a generated load of 3.7V (nominal voltage of battery) at 0.05A (Inominal) to the output terminals of the lithium-ion charging module.
7. Taking a measurement of the output voltage, ensure that it is within the specified range of 3.0V-4.2V (Vmin-Vmax).
8. Repeat this process, however adjust the load to 0.1A (Imax) and be sure the output voltage still remains within the voltage range.

In order to verify the properties of hybrd_slr_pwr_enclsr_mech: (CAN'T VERIFY UNTIL BLOCK 2 IS COMPLETE AS THAT IS THE ENCLOSURE BLOCK)

9. Have 5 test subjects attempt to screw and unscrew the M-13 connectors to ensure ease of use.
10. Have 5 test subjects shake the enclosure to ensure parts are securely fastened on standoffs. System should remain functioning after the shake test.

4.3.6 References and File Links

6.1 References

1. "18-dec-2019 56312e37 rylr896 - reyax.com." [Online]. Available: https://reyax.com/tw/wp-content/uploads/2019/12/RYLR896_EN.pdf. [Accessed: 08-Jan-2022].
2. "ATMEGA328P - Microchip Technology." [Online]. Available: https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf. [Accessed: 08-Jan-2022].
3. "MS5803-14BA miniature 14 bar module - sparkfun electronics." [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Weather/ms5803_14ba.pdf. [Accessed: 08-Jan-2022].
4. "TP4056 1a standalone linear Li-Lon Battery Charger with ..." [Online]. Available: https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Prototyping/TP4056.pdf. [Accessed: 08-Jan-2022].

6.2 File Links

1. LORA Module Datasheet
2. Pressure Sensor Datasheet
3. Atmega328P Datasheet
4. Battery Charging IC Datasheet

4.3.7 Revision Table

1/2/22	Nicholas Ung: Initial creation of document
1/5/22	Nicholas Ung: Initial Drafting of Sections 4.1.1, 4.1.2, 4.1.3, and 4.1.4
1/7/22	Nicholas Ung: Initial Drafting of Sections 4.1.5, 4.1.6, and 4.1.
1/18/22	Nicholas Ung: Updates to section 4.1.5, added additional property to last interface
1/21/22	Nicholas Ung: Updates to formatting, cleaned up document, removing possessive adjectives.

4.4 Enclosure Block

4.4.1 Description:

The purpose of this block is to securely contain and protect the system components, whilst also serving as the direct access point for potential hardware troubleshooting and repairs. This system needs to be within a close proximity to the irrigation gates, and because of this, require design consideration for weather resistance. Whilst the enclosure may be technically not as complex as other blocks, it is an extremely important component of our design. Having a poorly designed and functioning enclosure will likely result in a complete system failure, and damage to the hardware.

4.4.2 Design:

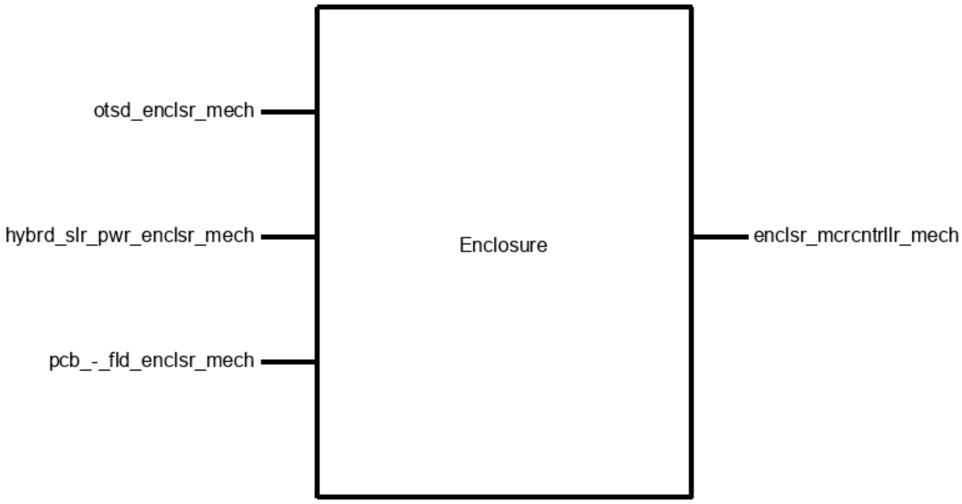


Figure 11: Black Box Diagram for Enclosure Block

Figure 13: M13 Style Aviator Connector to be used in order to easily connect and disconnect field devices to the enclosure, whilst also maintaining weather resistance

Figure 14: Cable glands to be used when spanning wire from enclosure to one end of the aviator cable to be attached to a field device.

Figure 15: Reference mounting plate that will be used to affix PCBs, battery, and power system to. Can be taken in and out of enclosure for ease of use.

4.4.3 General Validation

As far as options for an enclosure go, there were many limitations to a custom 3D printed design. The first issue is primarily with constraints to the machinery and process of 3D printing, versus injection molded plastic, which the vast majority of pre built enclosures are. A rather large commercial 3D printer has a typical print area of 10”x10”. Along with this, filament structures do not weather as well as an injected molded plastic, and oftentimes require much more material to have the same rigidity. For these reasons, a pre assembled enclosure was chosen for the design, and will be modified according to fit the needs of the system.

The mounting plate was chosen as an easier way to mount the components to a rigid plate outside of the enclosure. This will be made of a piece of acrylic or plexiglass, and standoffs will be placed according to the holes designed into the PCBs, in order to fasten them to the plate. This plate will then be placed down into the enclosure and fixed to the plate via screws or standoffs.

In order to maintain weather resistance while passing wires through the enclosure, gasketed cable glands will be used. These offer a waterproofness from the gasketting, while also providing strain relief for field device cabling. In order to meet the project requirement that devices can be detached from the enclosure, M13 style aviator connectors will be used. A small portion of wire will come out of the cable gland from the enclosure, and be terminated with one end of the connector. The other end will be the termination of the respective field device. These can then be plugged in via the integrated pins, and the collar screwed close to seal the gasket.

4.4.4 Block Validation

Table 11: Interface Properties for pcb_-_fld_enclsr_mech

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?

pcb_-_fld_enclsr_mech

Fasteners: M4 Bolts	These were chosen due to the fact that they are a standard and readily available part used for mounting/fastening	Testing has been done to verify that M4 bolts will indeed work for the spacing on the PCB and mounting plate.
Height: 2.95in	This is currently tentative, but it is the assumed spacing between the center point of top and bottom mounting holes.	During the PCB design, group member Eric Van Klaveren will ensure that the tolerances and spacing between mounting holes is this length.
Width: 3.95in	This is currently tentative, but it is the assumed spacing between the center point of top and bottom mounting holes.	During the PCB design, group member Eric Van Klaveren will ensure that the tolerances and spacing between mounting holes is this length.

Table 12: Interface Properties for enclsr_mcrcntrllr_mech

enclsr_mcrcntrllr_mech

Fasteners: M4 Bolts	These were chosen due to the fact that they are a standard and readily available part used for mounting/fastening	Testing has been done to verify that M4 bolts will indeed work for the spacing on the PCB and mounting plate.
Height: 2.95in	This is currently tentative, but it is the assumed spacing between the center point of top and bottom mounting holes.	During the PCB design, group member Eric Van Klaveren will ensure that the tolerances and spacing between mounting holes is this length.
Width: 3.95in	This is currently tentative, but it is the assumed spacing between the center point of top and bottom mounting holes.	During the PCB design, group member Eric Van Klaveren will ensure that the tolerances and spacing between mounting holes is this length.

Table 13: Interface Properties for hybrd_slr_pwr_enclsr_mech

hybrd_slr_pwr_enclsr_mech

Fasteners: Standoffs	Standoffs were chosen as the method of fastening for ease of use and security.	A solid base with standoffs can be designed and installed into the interior of the enclosure, adhered to the back panel. There will be holes implemented into the PCB in order to fasten the components to the back panel of the box. This allows for parts to be removed with the use of standoff screws, while solidly attaching components to the enclosure.
Fasters: Screw	Screws were chosen for the solar panel installation for convenience.	The solar panel chosen for this design includes mounting hardware in order to fasten the solar panel to a wooden post.

Passthrough: M-13	M-13 connectors were chosen for their ease of use and ability to maintain element resistant properties.	M-13 connectors will be used to connect external devices, in this case the solar panel, to the internal hardware. These are easily sourceable in gasketed versions to maintain IP67 resistance. These also allow for quick connection/disconnection so external devices can be removed from the enclosure.

Table 14: Interface Properties for otsd_enclsr_mech

otsd_enclsr_mech

Fasteners: M4 Standoffs	Standoffs were chosen as the method of fastening for ease of use and security.	The standoffs will be installed inside the enclosure and coordinate with holes located on the perimeter of the mounting plate. It will then be fastened down with M4 bolts, similarly to the system PCBs.
Fasters: Lag Screws	Lag screws were chosen to easily affix the enclosure to a 2x4 post.	Lag screws or lag bolts are a standard fastener when affixing something to a piece of lumber.
Weather Resistance: IP65	IP65 is a standard measurement of weather proofness, and generally accepted for outdoor applications that do not include being submerged in water.	The enclosure is IP67 rated, beyond the spec of IP65. Both of the cable glands and aviator connectors are waterproof rated (IP ratings only apply to enclosures.)

4.4.5 Verification Process

In order to verify the properties of pcb_-_fld_enclsr_mech:

1. Fasteners (M4 Bolts): Using a standard M4 bolt (4mm diameter) place PCB on the M4 standoffs and screw on bolts. The bolts should not interfere with any surrounding surface components, and not have any clearance issues.
2. Height (2.95in): Using a pair of calipers, measure the distance between the center points of the top and bottom mounting holes. This should be at 2.95in, or within a reasonable tolerance to allow for measurement error.
3. Height (2.95in): Using a pair of calipers, measure the distance between the center points of the top and bottom mounting holes. This should be at 2.95in, or within a reasonable tolerance to allow for measurement error.

In order to verify the properties of enclsr_mcrcntrllr_mech

4. Fasteners (M4 Bolts): Using a standard M4 bolt (4mm diameter) place PCB on the M4 standoffs and screw on bolts. The bolts should not interfere with any surrounding surface components, and not have any clearance issues.
5. Height (2.95in): Using a pair of calipers, measure the distance between the center points of the top and bottom mounting holes. This should be at 2.95in, or within a reasonable tolerance to allow for measurement error.
6. Height (2.95in): Using a pair of calipers, measure the distance between the center points of the top and bottom mounting holes. This should be at 2.95in, or within a reasonable tolerance to allow for measurement error.

In order to verify the properties of otsd_enclsr_mech:

7. Weather Resistance (IP65): Using water detection tape, place strips around the interior perimeter, as well as near cable gland points. Using a spray bottle, spray jets of water at the outside of the enclosure. Wipe outside dry to avoid water dripping in when opening. Inspect the tape locations and ensure that no water has been detected.
8. Fasteners (M4 standoffs): Have the user place the mounting plate into the enclosure. Should be a clear indication where standoffs are. Using standard M4 bolts, screw them onto the stand offs to fix plate to enclosure.
9. Fasteners (Lag screws): Enclosure will be affixed to a piece of 2x4 via lag screws. Have the test subject shake the 2x4 to ensure that the lag screws offer solid mounting of the enclosure to the post.

In order to verify the properties of hybrd_slr_pwr_enclsr_mech:

10. Have 5 test subjects attempt to screw and unscrew the M-13 connectors to ensure ease of use.
11. Have 5 test subjects shake the enclosure to ensure parts are securely fastened on standoffs. System should remain functioning after the shake test.

4.4.6 References and File Links

6.1 References

“How do cable gland work? the ultimate guide here!,” *Metal Cable Gland*, 20-Jun-2020. [Online]. Available: https://www.metalcablegland.com/how-do-cable-glands-work/. [Accessed: 10-Feb-2022].

6.2 File Links

[Cable Gland Datasheet]
[M4 Standoff Spec Sheet]

4.4.7 Revision Table

1/30/22	Nicholas Ung: Initial creation of document
2/1/22	Nicholas Ung: Initial Drafting of Sections 4.1.1, 4.1.2, 4.1.3, and 4.1.4
2/2/22	Nicholas Ung: Initial Drafting of Sections 4.1.5, 4.1.6, and 4.1.
2/3/22	Nicholas Ung: Updates to section 4.1.5, added additional property to last interface
2/4/22	Nicholas Ung: Updates to formatting, cleaned up document, removing possessive adjectives.

4.5 Pressure Sensor Block

4.5.1 Description

The purpose of this block is to set up both the MS5803 pressure sensor, as well as the BMP180 barometric pressure sensor in order for them to communicate with a microcontroller over I2C and relay pressure data from both the water. The data that is sent to the microcontroller will later be used to determine the depth of the water that the MS5803 sensor is submerged in for the purposes of calculating the flow rate of the water.

This is being done in order to get the necessary data to calculate the volumetric flow rate of an irrigation channel. This information is becoming more necessary to be collected with the droughts going on in the South-East of the United States, and local, state, and federal entities, such as the Bureau of Reclamation, are requiring this flow data be collected.

4.5.2 Design

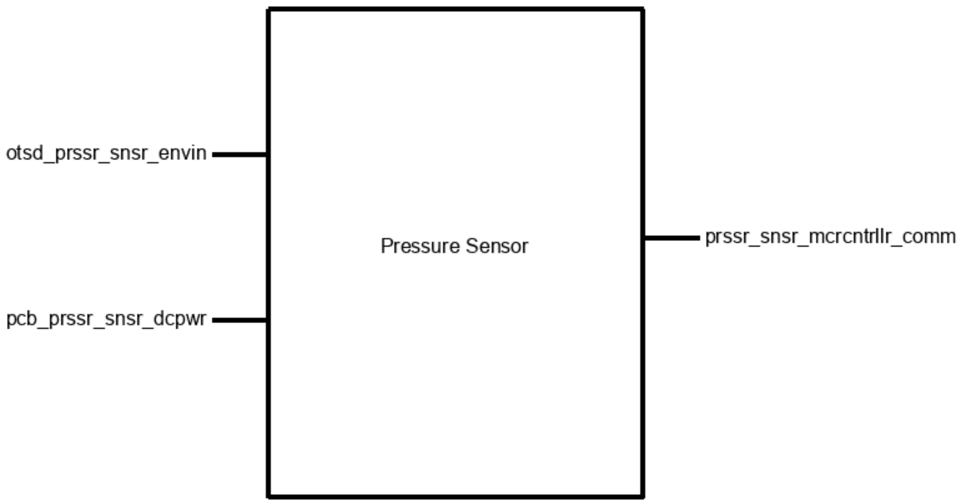


Figure x: Black Box Diagram for Pressure Sensor Block

Figure x: The MS5803-02BA Pressure sensor being used

4.5.3 General Validation

The MS5803-02BA pressure sensor is capable of withstanding up to 2 bar of pressure which is the pressure at a water depth greater than 20 meters which is more than enough for our purposes. It is capable of 24 bits of precision, and promises an accuracy of +/- 2.5mbar which is more than enough to fit the +/- 5% accuracy requirement that we have set. At a price point of less than $35 it is well within the budget of the project. Alternative choices include the rest of the MS5803 family of pressure sensors which range from being able to handle 1 bar up to 14 bar. The MS5803-02BA was chosen due to being the lowest price while still being able to handle pressures over 1 bar which would not be able to handle the amount of pressure required for our measurements.

The BMP180 sensor is able to detect the barometric pressure between 300 and 1100hPa which covers far beyond the typical range of barometric pressures. It is being used to determine the baseline pressure from the atmosphere so that the water pressure can more accurately be determined, since the barometric pressure changes regularly and has an effect on the measured pressure of water. This was chosen based on the price and availability, as it was less than $5 and able to be shipped within a week.

4.5.4 Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?

pcb_prssr_snsr_dcpwr

$I_{nominal}$: 8 µA	This value was chosen based on the sum of values given in the MS5803 pressure sensor datasheet [1]. As well as the BMP180 barometric pressure sensor datasheet [2]	From the Standby supply current value in the Electrical Characteristics table, Pg.2, in the MS5803 pressure sensor datasheet [1] As well as the Standby current value in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2]
I_{peak}: 32uA	This value was chosen as 4 times the nominal current in case of unforeseen circumstances	The devices are more than capable of handling this current based on the values in the MS5803 pressure sensor datasheet [1] As well as in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2]
V_{max}: 3.6V	This value was chosen based on the values given in the MS5803 pressure sensor datasheet [1]. As well as the BMP180 barometric pressure sensor datasheet [2]	From the Operating Supply voltage value in the Electrical Characteristics table, Pg.2, in the MS5803 pressure sensor datasheet [1]. As well as the Supply voltage value in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2]
V_{min}: 1.8V	This value was chosen based on the values given in the MS5803 pressure sensor datasheet [1.]As well as the BMP180 barometric	From the Operating Supply voltage value in the Electrical Characteristics table, Pg.2, in the MS5803 pressure sensor datasheet [1] As well as the

	pressure sensor datasheet [2]	Supply voltage value in the Electrical Characteristics table, Pg. 6, in the BMP180 barometric pressure sensor datasheet [2]

prssr_snsr_mcrcntrllr_comm

Datarate: 400 kHz	This value was chosen based on the value given in the MS5803 pressure sensor datasheet [1]. Since the value for datarate given in the BMP180 barometric pressure sensor datasheet [2] is higher.	From the Serial data clock value in the Digital Inputs table, Pg.4, in the MS5803 pressure sensor datasheet [1]. As well as the Clock input frequency value in the I2C Specification table, Pg. 19, in the BMP180 barometric pressure sensor datasheet
Protocol: I2C	I2C was chosen over SPI due to having access to 4 wire cables which would be able to send power and I2C data to the MS5803 pressure sensor, and BMP180 barometric pressure sensor, while SPI would require more wires.	The MS5803 pressure sensor is able to transmit data over I2C and advertises doing so on page 1 of the datasheet [1]. Same with the BMP180 barometric pressure sensor on page 2 of its datasheet [2].
$V_{nominal}$: Logic Low: 0V Logic High: 3.3V	This value was chosen based on the value given in the MS5803 pressure sensor datasheet [1]. As well as the BMP180 barometric pressure sensor datasheet [2]	From the Digital Inputs table, Pg.4, in the MS5803 pressure sensor datasheet [1], and the I2C specification table, Pg. 19, in the BMP180 barometric pressure sensor datasheet [2].

otsd_prssr_snsr_envin

Water in Channel Properties: Depth: 0-10m Pressure: 0-2 Bar	These are the value which the MS5803 sensor is able to handle based on the specifications in its datasheet [1]	From the Operating Pressure Range in the Pressure Output Characteristics table on page 3 of the datasheet [1]
Barometric Pressure: Pressure: 300-1100 hPa	These are the values which the BMP180 barometric pressure sensor is able to handle based on the specifications in its datasheet [2]	The BMP180 barometric pressure sensor advertises the pressure range on page 2 of its datasheet [2].

4.5.5 Verification Plan

The sensor's output will be tested against pressures of known values to test whether it's accurate. Then the sensor will be communicated with over I2C and have its data sent to a microcontroller. The value that was sent to the microcontroller will then be interpreted and checked against the pressure that should exist at the bottom of a bucket filled with a known level of water. The disparity between the two values will be the inaccuracy.

1. Plug in the microcontroller and connect the sensors to power, shown on the block diagram labeled as "prssr_snsr_mcrcntrllr_comm" and the I2C interface of the microcontroller, shown on the block diagram labeled "prssr_snsr_mcrcntrllr_comm"
2. Program the microcontroller to communicate with the sensors and process the data that they will be outputting.
3. Fill a bucket up to a known height of water and place the MS5803 sensor at the bottom of it.
4. Take the pressure data being output by the microcontroller and compare it against the expected pressure at the height of water chosen.
5. How close the two values are to each other will be used to determine the accuracy of the block

4.5.6 References

[1] "MS5803-02BA miniature 2 bar module," Octopart, Aug-2017. [Online]. Available: https://datasheet.octopart.com/MS580302BA01-00-TE-Connectivity-datasheet-140103744.pdf

[2] "BMP180 digital pressure sensor -," Adafruit, 05-Apr-2013. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/BST-BMP180-DS000-09.pdf.

4.5.6 Revision Table

Date	**Changes**
1/7/2022	Initial Release
1/13/2022	Added BMP180 sensor details after requested to add air pressure data by project partner
1/20/2022	Formatted references to fit IEEE standard
2/13/2022	Updated document to match change to MS5803-02BA 2 bar pressure sensor

4.6 Microcontroller Block

4.6.1 Description

The Microcontroller Clode Block being championed by Alexander Eamons is responsible for communicating with the Pressure Sensor block to obtain the pressure data, taking in user data about the channel that the pressure sensor is placed in, and using those parameters to calculate the flow rate using Manning's Equation. The microcontroller will also manage storing, sending, and receiving data wirelessly through the device in the Data Transmission block. This will require another microcontroller in order to transmit data between.

This block will be communicating with pressure sensor devices over I2C, and using UART to communicate with the transceiver, and SPI to communicate with the Zittop SD Card reader. As well as reading data from a file provided by the GUI - Programmable Input block.

This block is necessary in order to collect data from the field and store it until it is requested by a remote user, and then the data stored with the "in the field" microcontroller will be sent to the "in the office" microcontroller wirelessly upon request.

4.6.2 Design

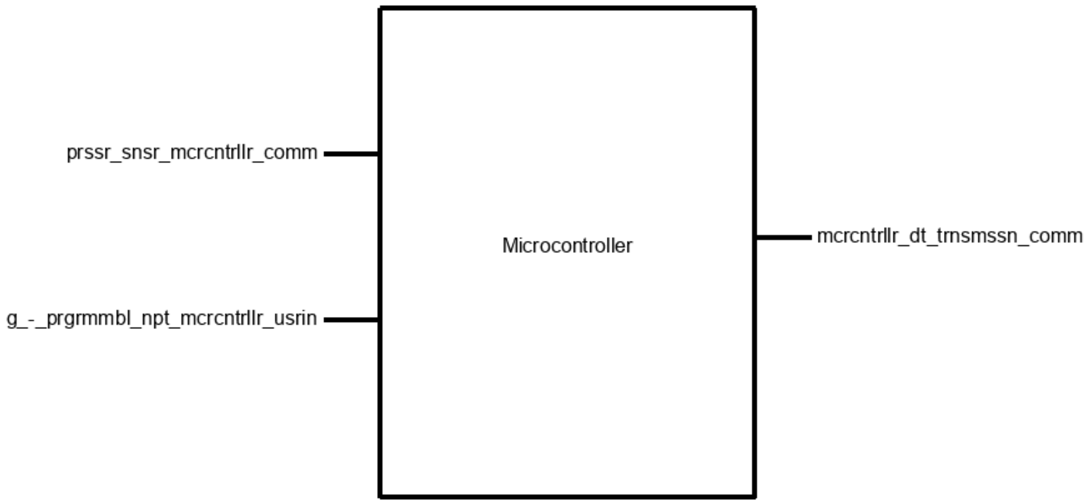


Figure x: Black Box Diagram for Microcontroller Block

4.6.3 General Validation

The microcontroller is going to be needed to be able to communicate over UART, SPI, and I2C to 3.3V devices. The Arduino Nano was chosen due to availability, cost, and ease of programming and connection to a computer over USB. The Arduino Nano is capable of performing all of the tasks which we need. Though it comes with the drawback of operating at 5V which will cause difficulties when interfacing with 3.3V devices. Currently though, mainly due to availability, our team has decided to go with the Arduino Nano.

The first choice was the Arduino Pro Mini 328 (3.3V) due to being a 3.3V logic level device and being able to connect directly to all of the 3.3V components which we have been working with. Another choice which comes from Seeed is the Seeeduino Xiao which also operates at 3.3V. Other options include the Genuino series, Arduino Zero series, and any other board using the ATMega328 board.

4.6.4 Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?

prssr_snsr_mcrcntrllr_comm: Input

Datarate: 400 kHz	This value was chosen based on the value given in the MS5803 pressure sensor datasheet [1]. Since the value for datarate given in the BMP180 barometric pressure sensor datasheet [2] is higher.	From the Serial data clock value in the Digital Inputs table, Pg.4, in the MS5803 pressure sensor datasheet [1]. As well as the Clock input frequency value in the I2C Specification table, Pg. 19, in the BMP180 barometric pressure sensor datasheet
Protocol: I2C	I2C was chosen over SPI due to having access to 4 wire cables which would be able to send power and I2C data to the MS5803 pressure sensor, and BMP180 barometric pressure sensor, while SPI would require more wires.	The MS5803 pressure sensor is able to transmit data over I2C and advertises doing so on page 1 of the datasheet [1]. Same with the BMP180 barometric pressure sensor on page 2 of its datasheet [2].
$V_{nominal}$: Logic Low: 0V Logic High: 3.3V	This value was chosen based on the value given in the MS5803 pressure sensor datasheet [1]. As well as the BMP180 barometric pressure sensor datasheet [2]	From the Digital Inputs table, Pg.4, in the MS5803 pressure sensor datasheet [1], and the I2C specification table, Pg. 19, in the BMP180 barometric pressure sensor datasheet [2].

mcrcntrllr_dt_trnsmssn_comm : Output

Datarate: Baud Rate: 115,200	Based on the specifications of the RYLR896 transceiver that is being used	From the Specification table on the RYLR896 wireless transceiver description page [4]
Other: Logic High - 3.3V Logic Low - 0V	These are the expected logic levels due to it being a 3.3V device and the datasheet	From the Specification table on the RYLR896 wireless transceiver description page [4]
Protocol: UART	This is the only form of communication that the	From the Specification table on the RYLR896 wireless

	RYLR896 transceiver is able to use	transceiver description page [4]

pcb_-_fld_mcrcntrllr_dcpwr : Input

Inominal: 19mA	This is the expected current draw based on the microcontroller specs on the store page	This information was provided in the “Tech Specs” section of the Arduino Nano’s store page[1]
Ipeak: 40mA	It’s the expected value times 2 plus a bit	If the device draws less than this during full operation then it has met this requirement
Vmax: 7.0V	This is the value that was provided on the store page [1]	This information was provided in the “Tech Specs” section of the Arduino Nano’s store page[1]
Vmin: 12.0V	This is the value that was provided on the store page [1]	This information was provided in the “Tech Specs” section of the Arduino Nano’s store page[1]
Vnominal: 5.0V	This is the boards Operating voltage according to the store page [1]	This information was provided in the “Tech Specs” section of the Arduino Nano’s store page[1]

g_-_prgrmmbl_npt_mcrcntrllr_usrin : Input

Other: Plaintext	The data needs to be able to be understood and easily stored and edited in the file	The Arduino Nano allows files be viewed and edited when connected to a computer so seeing the file on the board will be enough
Other: Length Width Height Information	This is the data that needs to be stored about the channel in order to	If the data stored is enough to solve for flow rate when provided a pressure value then the interface send all the necessary data
Other: <32kB	The file needs to fit into the flash memory of the Arduino nano which has 30kB free which also needs to be used	This information was provided in the “Tech Specs” section of the Arduino Nano’s store page[1]

	for code	

4.6.5 Verification Plan

1. Connect “in the field” microcontroller to computer
2. Load test values into microcontroller
3. Connect the pressure sensor to the microcontroller
4. Ensure that the device is communicating with the pressure sensor successfully
5. Connect the wireless transceiver to both the in the field and in the office microcontroller
6. Ensure that the devices are communicating with each other successfully
7. Connect the SD card reader writer device.
8. Ensure that the devices are communicating with each other successfully
9. Unplug all of the devices

4.6.6 References

[1] *Arduino Nano*. Arduino Online Shop. (n.d.). Retrieved February 19, 2022, from https://store-usa.arduino.cc/products/arduino-nano/

[2] “MS5803-02BA miniature 2 bar module,” Octopart, Aug-2017. [Online]. Available: https://datasheet.octopart.com/MS580302BA01-00-TE-Connectivity-datasheet-140103744.pdf

[3] “BMP180 digital pressure sensor -,” Adafruit, 05-Apr-2013. [Online]. Available: https://cdn-shop.adafruit.com/datasheets/BST-BMP180-DS000-09.pdf.

[4] https://arduino-forth.com/article/composants_LoraREYAX LORA wireless transciever

4.6.7 Revision Table

Date	Changes
2/1/2022	Initial Release

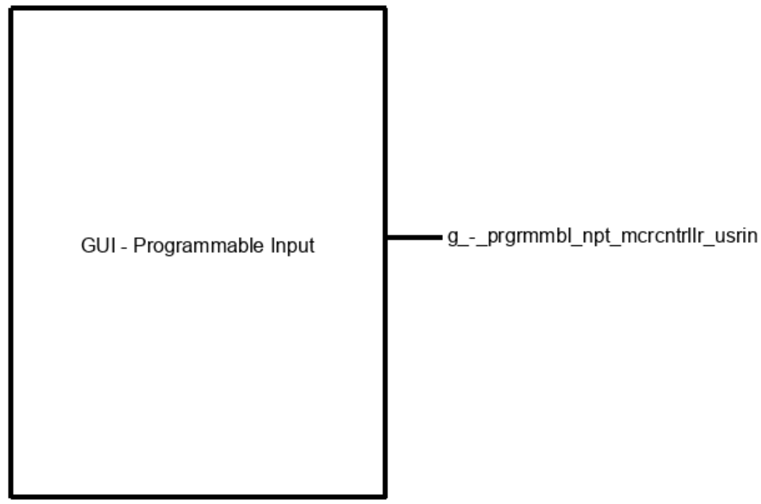
2/15/2022	Alexander Eamons: Edited the interface validation to fill out the two missing columns
2/18/2022	Alexander Eamons: Updated the General Validation section to include the fact that we will be using the Arduino Nano. Updated the Interface Validation section to match the Block Diagram Entry page

4.7 GUI Programmable Block

4.7.1 Description

The programmable input block will take in user input and relay it to the microcontroller. This needs to be done so that the system can be universally placed in any irrigation gate. This input will be the dimensions of the gate, length, width and height. This data will be sent to the data interpretation block so that the calculations can be based on accurate and specific dimensions. This will involve an interface on an application.

4.7.2 Design




```
classdef liuqiao_song < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure           matlab.ui.Figure
        UITable            matlab.ui.control.Table
        ReadingDataButton  matlab.ui.control.Button
        UIAxes             matlab.ui.control.UIAxes
        PlotingDataButton  matlab.ui.control.Button
        LampLabel          matlab.ui.control.Label
        Lamp               matlab.ui.control.Lamp
        SwitchLabel        matlab.ui.control.Label
        Switch             matlab.ui.control.Switch
    end

    % Callbacks that handle component events
    methods (Access = private)

        % Button pushed function: PlotingDataButton
        function PlotingDataButtonPushed(app, event)
          t=load("C:\Users\Liuqiao Song\Desktop\matlab_app\liuqiao_matlab_app\xy.mat");
           %plot(t.rws(:,1));
           plot(app.UIAxes,t.xy(:,1));
           %hold on;
           %plot(t.rws(:,2));
           %plot(app.UIAxes,t.rws(:,2));
           app.Lamp.Color='r';
```

```
            app.Switch.Value='On'

        end

        % Button pushed function: ReadingDataButton
        function ReadingDataButtonPushed(app, event)
            t=load("C:\Users\Liuqiao Song\Desktop\matlab_app\liuqiao_matlab_app\xy.mat");
            app.UITable.Data=t.xy;
            app.Lamp.Color='r';
            app.Switch.Value='On'
        end

        % Value changed function: Switch
        function SwitchValueChanged(app, event)
            value = app.Switch.Value;

        end
    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Position = [100 100 584 411];
            app.UIFigure.Name = 'UI Figure';

            % Create UITable
            app.UITable = uitable(app.UIFigure);
            app.UITable.ColumnName = {'RegionA'; 'RegionB'};
            app.UITable.RowName = {};
            app.UITable.ForegroundColor = [0 1 1];
            app.UITable.Position = [45 187 196 185];

            % Create ReadingDataButton
            app.ReadingDataButton = uibutton(app.UIFigure, 'push');
            app.ReadingDataButton.ButtonPushedFcn = createCallbackFcn(app,
@ReadingDataButtonPushed, true);
            app.ReadingDataButton.BackgroundColor = [0.9294 0.6902 0.1294];
            app.ReadingDataButton.FontColor = [0 0 1];
            app.ReadingDataButton.Position = [76 99 100 22];
```

```
        app.ReadingDataButton.Text = 'ReadingData';

        % Create UIAxes
        app.UIAxes = uiaxes(app.UIFigure);
        title(app.UIAxes, 'Curves of Regions A and B')
        xlabel(app.UIAxes, 'month')
        ylabel(app.UIAxes, 'volume(1000m^3)')
        app.UIAxes.GridAlpha = 0.15;
        app.UIAxes.MinorGridAlpha = 0.25;
        app.UIAxes.Box = 'on';
        app.UIAxes.Color = [1 0 1];
        app.UIAxes.XGrid = 'on';
        app.UIAxes.YGrid = 'on';
        app.UIAxes.Position = [270 187 300 185];

        % Create PlotingDataButton
        app.PlotingDataButton = uibutton(app.UIFigure, 'push');
        app.PlotingDataButton.ButtonPushedFcn = createCallbackFcn(app,
@PlotingDataButtonPushed, true);
        app.PlotingDataButton.BackgroundColor = [0 1 0];
        app.PlotingDataButton.FontColor = [1 0 0];
        app.PlotingDataButton.Position = [383 99 100 22];
        app.PlotingDataButton.Text = 'PlotingData';

        % Create LampLabel
        app.LampLabel = uilabel(app.UIFigure);
        app.LampLabel.HorizontalAlignment = 'right';
        app.LampLabel.VerticalAlignment = 'top';
        app.LampLabel.Position = [244 102 36 15];
        app.LampLabel.Text = 'Lamp';

        % Create Lamp
        app.Lamp = uilamp(app.UIFigure);
        app.Lamp.Position = [295 99 20 20];

        % Create SwitchLabel
        app.SwitchLabel = uilabel(app.UIFigure);
        app.SwitchLabel.HorizontalAlignment = 'center';
        app.SwitchLabel.VerticalAlignment = 'top';
        app.SwitchLabel.Position = [258 27 41 15];
        app.SwitchLabel.Text = 'Switch';

        % Create Switch
        app.Switch = uiswitch(app.UIFigure, 'slider');
```

```
            app.Switch.ValueChangedFcn = createCallbackFcn(app, @SwitchValueChanged, true);
            app.Switch.Position = [256 57 45 20];

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = liuqiao_song

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
        end

        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
```

4.7.3 General Validation

App Designer lets you create professional apps in MATLAB without having to be a professional software developer. Drag and drop visual components to lay out the design of your graphical user interface (GUI) and use the integrated editor to quickly program its behavior.

4.7.4 Interface Validation

Interface Name	**Properties**
g_-_prgrmmbl_npt_mcrcntrllr_usrin	• **Other:** Plaintext • **Other:** Length Width Height Information • **Other:** <32kB

The plain text is defined through the code in matlab app designer. After it combined onto an exe download file. The storage will smaller than 32KB.

4.7.5 Verification Plan

Run the program in MATLAB, run smoothly, and generate the user interface

4.7.6 Reference

E. C. Martin, “Measuring Water Flow in Surface Irrigation Ditches and Gated Pipe,” arizona.edu, Dec-2011.Available:https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1329.pdf.

4.7.6 Revision Table

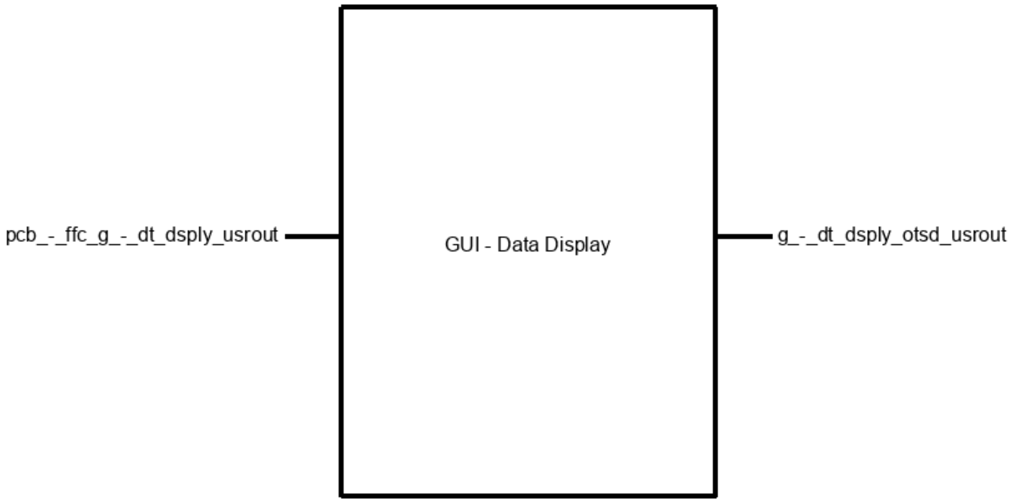
Date	**Changes**
2/1/2022	Initial Release
2/17/2022	Code in matlab finished
2/18/2022	Correct the errors to load data

4.8 GUI Data Display Block

4.8.1 Description

The user interface is the last module of the entire project that we have made. It can be an application or an interface, or a display screen to display the changes in regional water volume, visualize the actual data, and exchange information with other modules.

4.8.2 Design



4.8.3 General Validation

The data display will will be visualized so that users can see the change curve within a certain period of time.The general validation is the application could let the limited people to use the app which means they could log into the application. And the data will be displayed in the application and the format will be the suitable way to show the data.

4.8.4 Interface Validation

Interface Name
g_-_dt_dsply_otsd_usrout   Data from at least previous 24 months
graph of water level

pcb_-_ffc_g_-_dt_dsply_usrout   minimum of 2 region to monitor
2 years of data water level value

The timeline and the water volume will showed on the curve of the interface

4.8.5 Verification Plan

The data will come from the pcb office and the higher the value. The higher the pressure, the higher the water content at this time. The lower the value, the smaller the pressure, which means that the water content is smaller at this time. The app designer of GUI will record the values on the data and reflect them in the image, and the user can see the transformation curve The screen shot below is the curve of the water volume of the field in the limited time period.

C:\Users\Liuqiao Song\Desktop\matlab_app\liuqiao_matlab_app\xy.mat"
This is the address of the data

4.8.6 Reference

"What is Lora®?," Semtech. [Online]. Available: https://www.semtech.com/lora/what-is-lora.

4.8.7 Revision Table

Date	Changes
2/25/2022	Initial Release

2/28/2022	Create random number in Matlab to test
3/1/2022	Add user interface properties

5 - Block Validations

5.1 - Universal Constraints

5.1.1

The final system does not contain a breadboard, instead it has two custom PCBs to house the microcontroller and any other connectors.

5.1.2

The final system contains two custom PCBs, the field PCB and the office PCB, as detailed above. The user interface is a custom PC application that satisfies this universal constraint.

5.1.3

The enclosure is ruggedly designed and mounted, as verified in the block analysis in section 4. It was tested and accepted by the professors.

5.1.4

The PCB uses connectors for all connections, and the enclosure also has connectors for everything entering and leaving the space. These were both verified in block checkoffs.

5.1.5

The power supply maintains at least 65% efficiency through the process of voltage and current regulation from input power to output power.

5.1.6

Each of the blocks contain significant student contribution, even when pre-purchased modules are involved. The project uses well under 50% pre-purchased modules, an estimation would be around 20% of the project is pre-purchased modules, with the other 80% being custom circuits, code and a GUI.

5.2 - Data Storage

5.2.1 - Requirement

The device will store raw pressure data for 6 months without filling up to 80 percent memory. Thus allowing it to continue normal operation during a period of that length.

5.2.2 - Testing Process

1. Power on the field system
2. Let the system run for 6 hours
3. Power off the field system
4. Take the SD card out of the system and plug it into a computer
5. Find the size of the file that was created by the system during those 6 hours.

6. Multiply that size by 744 to get the amount of space that would be taken up in 6 months of operation (4 6-hour segments per day * 31 days per month * 6 months, 4*31*6 = 744)
7. Compare that size with 80% of the total size of the SD card, and verify that it is less

5.2.3 - Testing Evidence

The requirement was verified by first running the device for a 6 hour period. The videos linked below show the start and result of running the system for over 6 hours

6 Hour Testing Video Part 1

6 Hour Testing Video Part 2

The images below are showing that after the 6 hours of data has been collected the SD card was removed from the enclosure and plugged into a computer and the file size was checked and it came out to be 32768 Bytes.

32768 * 744 = 24.4MB which is much less than 80% of the 32GB that the SD card can hold.

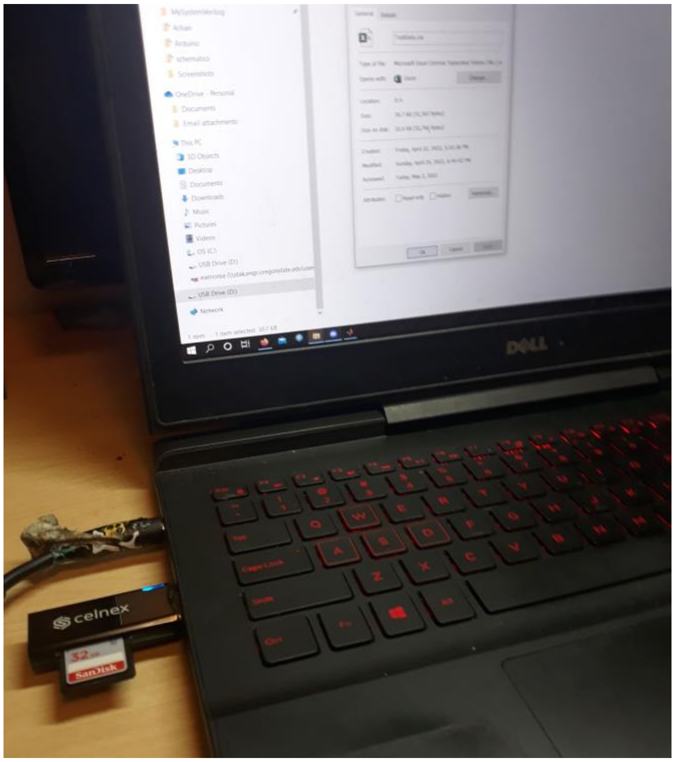


Figure 1: image of the SD card plugged into a computer

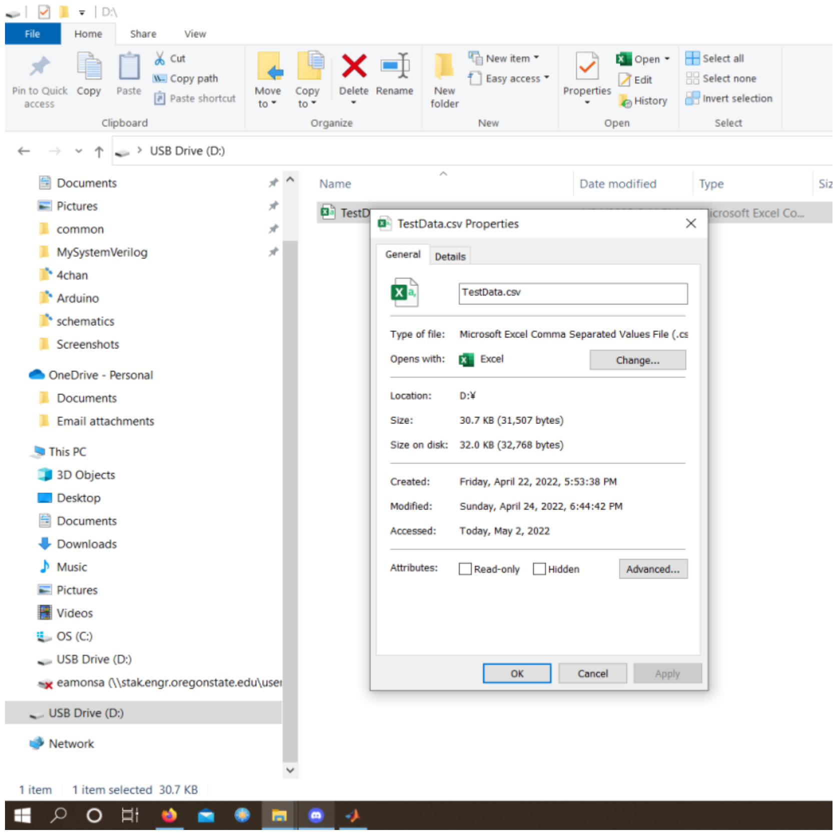


Figure 2: Screenshot of the SD card filesystem

5.3 - Enclosure

5.3.1 - Requirement

The system will be ruggedly enclosed, being able to withstand rain penetrating the enclosure from above. Subjected to water jets from above, there will be no water ingress inside the enclosure.

5.3.2 - Testing Process

1. Locate a water nozzle (shower head) in order to spray low pressure water jets at the enclosure.
2. Place water detection paper strips inside the enclosure around the perimeter, and on electronics.
3. For 3 minutes, spray direct water jets onto the enclosure from the water nozzle (shower head).
4. After 3 minutes, turn off the water, and dry off the enclosure to clear excess water.
5. Inspect the interior of the enclosure. Ensure that no water has entered the enclosure, electronics are still working, and water detection strips are dry.

5.3.3 - Testing Evidence

Linked below is a video that shows the 3 minute test cycle of a constant water stream being directed at the enclosure, and subsequent inspection of the internals of the enclosure.

Enclosure Testing Video

5.4 - Data Transmission

5.4.1 - Requirement

The system will have a data transmission range of 1km in normal operations, with a clear line of sight.

5.4.2 - Testing Process

Method: Demonstration

1. Set up the system and move the receiver to a location 1km away with a direct line of sight.
2. Verify using a test script that data is being received.

5.4.3 - Testing Evidence

The range test video shows the system placed 1km away from the receiver and it verifies using a test script that data is received.

Range Test

5.5 - Power

5.5.1 - Requirement

The system will operate normally for one month without charging. In order to achieve this the system will be designed to charge the battery at a faster rate than it discharges, leading to a net positive charge over a 24 hour period. This means that the battery will constantly remain topped off through the day, discharge some overnight, and be recharged fully throughout the day.

5.4.2 - Testing Process

1. Detach the positive 5V output from the solar power supply from the system load.
2. Using a Digital Multimeter to measure amperage, attach the positive probe to the positive 5V terminal.
3. Now taking the negative probe of the DMM, attach it to the positive 5V input to the load.
4. Taking recording of normal operation, observe the maximum measured load current.
5. Now detach the 5V solar cell input to the battery charger.
6. Attach the positive lead of the DMM to the 5V output of the solar cell.
7. Attach the negative lead of the DMM to the 5V input of the battery charger.
8. Similar to step 4, observe the input current under normal operation.
9. Compare the solar input and load currents, and ensure that the charge rate exceeds or equals the discharge rate of the battery.

5.4.3 - Testing Evidence

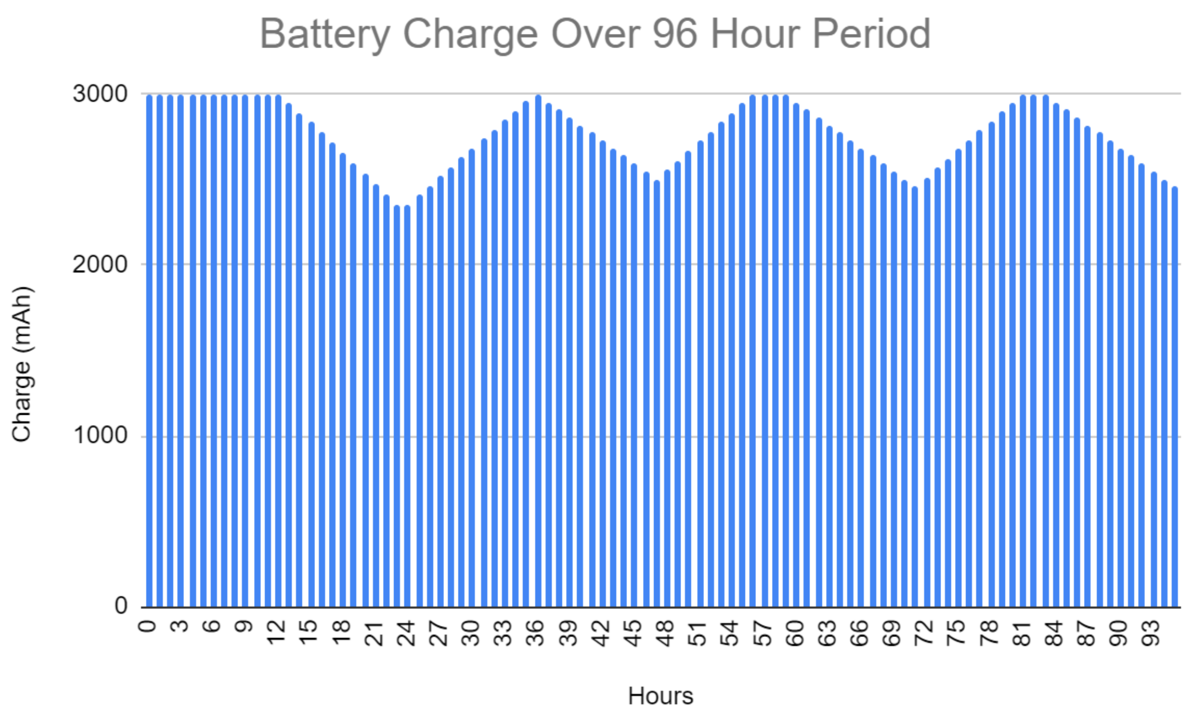
After taking test measurements of the load current, it was apparent that it has a very consistent periodic behavior. Operating on a 5.5 second period, it remains at 43 mA for 5 seconds, and spikes to around 70 mA for 0.5 seconds. This averages out to approximately 45 mA of constant current draw.

Load Current Test Video

After taking test measurements of the input current from the solar panel to the battery charger, we saw at a minimum 100 mA of charge current. This was in non-ideal conditions, with most of the sun blocked by clouds.

Solar Input Current Test Video

Assuming half of the day is sunlight, during the day there is a net charge of +55 mAh, over 12 hours. This means that overall during the day, the battery receives a charge of 660mAh whilst simultaneously running. Overnight while there is no solar input, it will draw a total of 540 mAh of charge from the battery. Therefore the net positive charge generated by the solar during the day is enough to completely recharge the battery charge that was lost during the night.



This figure demonstrates the theoretical charge of the battery over a 96 hour period. It begins at 0 hours with a full battery and 12 hours of sunlight. It maintains full charge until the sun goes away and it discharges for 12 hours. Then the sun comes back and it charges back up. This cycle repeats itself, and it eventually stabilizes out to a repeating triangular like wave, constantly maintaining above ⅔ charge.

5.6 - Accuracy

5.6.1 - Requirement

The system will accurately monitor water flow within +/-20% for a period of 6 hours.

5.6.2 - Testing Process

1. Place the pressure sensor at the bottom of a stream of water that has a known volumetric flow
2. Power on the field system
3. Begin collecting data on office part of the system
4. Let the system run for 6 hours
5. Stop collecting data on the office part of the system
6. Calculate the water flow based on the readings that were taken.
7. Verify that the calculated readings are within +/-20% of the known flow rate

5.6.3 - Testing Evidence

The requirement was verified by first running the device for a 6 hour period. The videos linked below show the start and result of running the system for over 6 hours in the Santiam Canal in Lebanon, Oregon. This location was chosen due to having flow rate data collected by the United States Geological Survey (USGS) which the collected data will be able to be compared against. Data was collected on May 2, 2022 starting at 7:30am and ending at 1:30pm.

6 Hour Testing Video Part 1

6 Hour Testing Video Part 2

After collecting the data the flow rate measured by the USGS was acquired for the times of May 2, 2022 between the hours of 7:00am and 2:00pm. The highest flow rate value in that time frame was 102 cubic feet per second (CFS), and the lowest flow rate value in that time frame was 101 CFS.

```
# Data for the following 1 site(s) are contained in this file
#    USGS 14187600 LEBANON SANTIAM CANAL NEAR LEBANON, OR
# -----------------------------------------------------------------------------------
#
# Data provided for site 14187600
#            TS   parameter     Description
#        117139       00065     Gage height, feet
#        117140       00060     Discharge, cubic feet per second
#
# Data-value qualification codes included in this output:
#     P  Provisional data subject to revision.
#
agency_cd       site_no datetime        tz_cd   117139_00065    117139_00065_cd 117140_00060    117140_00060_cd
5s      15s     20d     6s      14n     10s     14n     10s
USGS    14187600        2022-05-02 00:00        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 00:15        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 00:30        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 00:45        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 01:00        PDT     2.81    P       103     P
USGS    14187600        2022-05-02 01:15        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 01:30        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 01:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 02:00        PDT     2.81    P       102     P
USGS    14187600        2022-05-02 02:15        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 02:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 02:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 03:00        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 03:15        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 03:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 03:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 04:00        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 04:15        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 04:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 04:45        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 05:00        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 05:15        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 05:30        PDT     2.78    P       100     P
USGS    14187600        2022-05-02 05:45        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 06:00        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 06:15        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 06:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 06:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 07:00        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 07:15        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 07:30        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 07:45        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 08:00        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 08:15        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 08:30        PDT     2.78    P       100     P
USGS    14187600        2022-05-02 08:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 09:00        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 09:15        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 09:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 09:45        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 10:00        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 10:15        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 10:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 10:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 11:00        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 11:15        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 11:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 11:45        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 12:00        PDT     2.80    P       102     P
USGS    14187600        2022-05-02 12:15        PDT     2.81    P       102     P
USGS    14187600        2022-05-02 12:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 12:45        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 13:00        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 13:15        PDT     2.81    P       102     P
USGS    14187600        2022-05-02 13:30        PDT     2.79    P       101     P
USGS    14187600        2022-05-02 13:45        PDT     2.80    P       101     P
USGS    14187600        2022-05-02 14:00        PDT     2.80    P       102     P
```

Figure 1: USGS Flow Rate Data

If all of the flow rate values that are calculated by the system using the data collected and Manning's equation are within the range of 80% of the high value, which is 81.6 CFS, and 120% of the low value, which is 121.2 CFS, then all of said values are within the +/-20% accuracy requirement.

After calculating the flow rate the highest value was found to be 98.12 CFS, and the lowest value was 94.37 CFS which is within the specified range therefore proving the accuracy of the system.

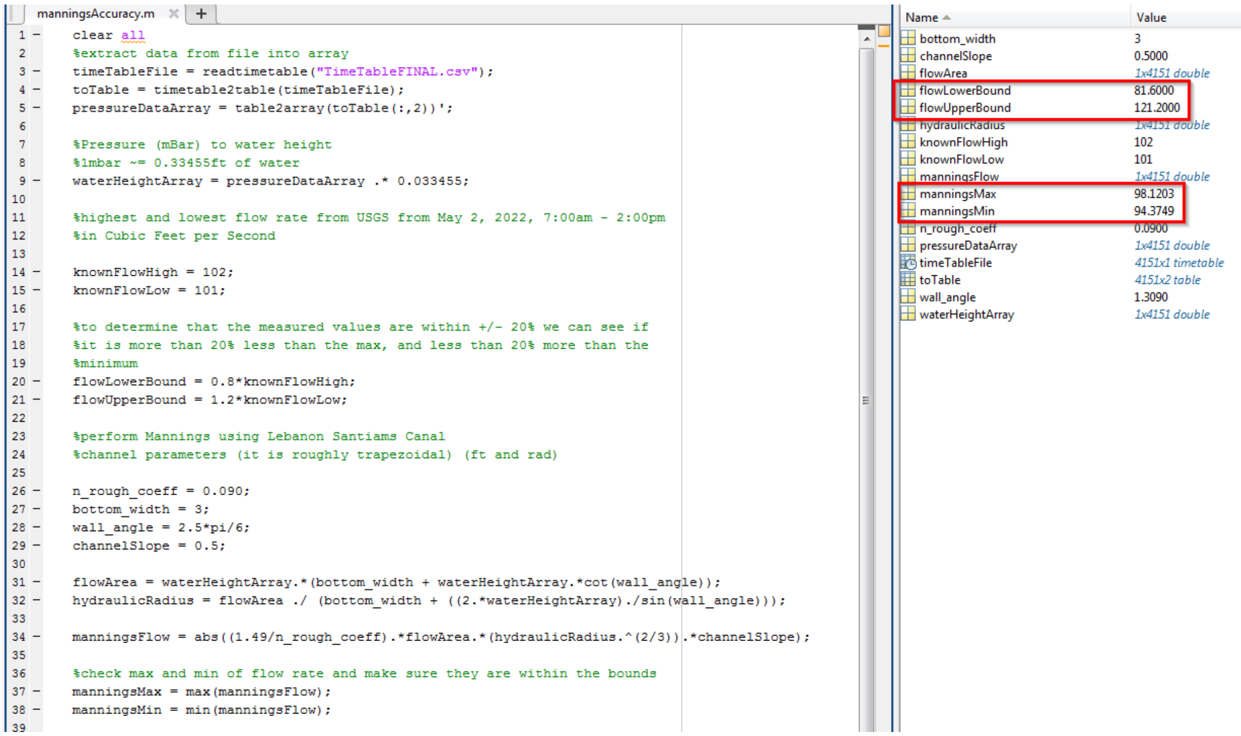


Figure 2: Matlab Script Calculating Flow Rate of Collected Data

5.7 - User Input

5.7.1 - Requirement

The system will allow for user defined inputs.

5.7.2 - Testing Process

Method: Demonstration

1. Open the user interface
2. Enter in gate parameters,for example bottom length, slope angle
3. Verify that the calculations for water volume are adjusted based on inputs.

5.7.3 - Testing Evidence

https://youtu.be/Y4yyY3TKtb4

https://youtu.be/a4FbuAx18aE

5.8 - Data Display

5.8.1 - Requirement

The system will display the recorded data as a plot in the setting time period. In the whole process, the user interface will show the water pressure, water level,water flow volume.

5.8.2 - Testing Process

1. Input the parameter
2. Choose model trapezoid，triangle，rectanhular and choose time period for 60 min,120min, 360 min

Method: Demonstration

1. Open the user interface
2. Verify that the volume is displayed

5.8.3 - Testing Evidence

https://youtu.be/Uvjc09WyGnI 120 min triangle
https://youtu.be/sC6fBgH7UaY 60 min trapezoid part 1
https://youtu.be/XYq4hHs_E8o 60 min trapezoid part 2
https://youtu.be/W8V052FW0ls 360 min rectangular

https://youtu.be/a4FbuAx18aE full video

5.9 - User Manual

5.9.1 - Requirement

The system contains a user manual with information on system setup in the field.

5.9.2 - Testing Process

Method: Inspection

1. Look at the user manual and verify that it contains information on system setup.

5.9.3 - Testing Evidence

User Manual

5.4 - References and File Links

User Manual
https://youtu.be/Uvjc09WyGnI 120 min triangle https://youtu.be/sC6fBgH7UaY 60 min trapezoid part 1 https://youtu.be/XYq4hHs_E8o 60 min trapezoid part 2 https://youtu.be/W8V052FW0ls 360 min rectangular https://youtu.be/a4FbuAx18aE full video
https://youtu.be/Y4yyY3TKtb4 https://youtu.be/a4FbuAx18aE
6 Hour Testing Video Part 1 6 Hour Testing Video Part 2
Load Current Test Video Solar Input Current Test Video
Range Test
Enclosure Testing Video
6 Hour Testing Video Part 1 6 Hour Testing Video Part 2

5.5 - Revision Table

Date	Changes
3/1/2022	Initial Release
3/5/2022	Data Storage and Enclosure Testing Process sections filled out
3/6/2022	Data Storage and Enclosure evidence added
3/11/2022	Update to Section 5.3.2, as well as update to linked video in 5.3.3
4/27/2022	Added sections 5.4-5.9

6 - Block Validations

6.1 - Future Recommendations

6.1.1 - Technical Recommendations

1. The wireless range of the system currently sits at 1km, but it can even be extended to 5 - 10km with proper antenna setup. This is utilizing LORA wireless technology, which is excellent for low bitrate sensor data. One way the system could be improved is by improving this range and bandwidth. However, that would require switching to a more powerful wireless technology, like cell phone wireless. This requires more power to send, and sometimes a license fee. There are a host of benefits that this brings though. First, it will allow for a more consistent long range signal. This means that the data loss rates are reduced and the system can be placed further from the data reception area. In addition, the current system needs a direct line of sight to achieve its maximum range, but the phone signal does not need that. This allows for a much broader range of applications. Also, since the cell phone signal has a larger bandwidth, more sensor data could be collected, therefore allowing for more accurate flow rate data. Here is a brief article that discusses the different types of wireless communication and their pros and cons: Wireless Communication.

2. The pressure sensor device is intended to communicate with the microcontroller over a relatively long range of a couple of meters, and this becomes a problem when using 3.3V I2C communication which is intended for communications over very short distances. Changing the communication protocol to one more suited for long range wired communications such as RS232 or RS422 and twisted pair cables would be more suited for the range requirement. This would also require either the changing of what pressure sensor is being used, as the current MS5803 is only capable of SPI and I2C communication, or a serial communication converter to change what protocol is being used near to the pressure sensor.

3. Currently the power system is in two pieces. There is the PCB with 18650 Lithium cell charging IC, some MOSFETS, and other power electronics. Then there is a battery cell holder that houses the 18650 Lithium-Ion cell. The power capability of this system is perfectly adequate for the system, however this system could be cleaned up and simplified. In the future, a way to improve it would be to integrate the battery cell holder into the PCB so it is one solid piece, eliminating the need for additional soldering. This would involve adding some additional traces to the input of the power system, and having those connect to the positive and negative terminals of the battery holder. Also a great addition in

the future would be to have some sort of battery health monitoring system. As of now there is not a way to tell the life cycle of the cell without doing some internal resistance and power cycle testing. Finding a way to integrate a battery monitoring system would be very beneficial to users of this system, alerting them when it is coming up on time to change the battery. This could also be implemented in a timer based way within the microcontroller code. Something as simple as a real time clock tracking a year or two and alerting the user to change the cell when the timer is up.

4. GUI improvements
   The GUI will show more accurate data, not just positive numbers. Negative numbers can also be displayed. And we plan to input data and present data at the same time. Currently, we need to find a way to box the data input and the data display into the same system.

6.1.2 - Global Impact Recommendations

1. The first global impact recommendations would be to create a system that is mass producible. As of now, our system is a fully-functioning prototype. To further increase the scalability of the product, more research needs to be done on the specific components selected in the system. Are there enough microcontrollers to make 100 systems? Are there enough pressure sensors? What is the shipping time of all of the components? What is the manufacturer lead time? When do these products reach End-of-Life? These are all things that need to be considered and have some further research in order to make this product more scalable and therefore have a greater global impact.
2. Another part of scalability is how universal the product is, or in other words, how many applications can it serve. The more applications, the larger the market for the product is. The current system has a function flow rate calculator, and it can function with a few different gate shapes and sizes. However, to increase the range of places the system could be used, the user interface needs to be expanded upon. This could be things like more advanced data viewing and manipulation, custom gate sizes, and even more settings to read flow in different environments other than just water gates.

6.1.3 - Teamwork Recommendations

1. The first recommendation that our team would give to a future group working on this project is to take advantage of the block building portion of the class. The purpose of this portion is to make your blocks so that they all connect with one another through the specified interface. This makes system integration easy because you already know how everything connects and all you have to do is

hook it up. However, this takes significant team communication and collaboration, because you all need to work together to decide how the blocks will connect. On the other hand, this lays the groundwork for your system integration and will save you even more time and make the process much smoother. This is something that our team did not do well enough and it caused some headaches when it came time to integrate. This also means your team needs a good timeline for the project, a good starting point is this Forbes article.

2. The second recommendation is to use your resources, particularly the professors. They have time allocated to meet with you and help you stay on track. We did not start having weekly meetings until spring term, but once we started having these meetings with Ingrid, our progress and quality of work increased tremendously because she helped guide us and keep us moving. We recommend setting up weekly meetings with one of your instructors in the beginning of winter term. Even if you don't yet have much to talk about, they will tell you what you need to do. In addition, this comes in handy when checking off your system because they have a solid understanding of how it works and they followed along with your process.

6.2 - Project Artifact Summary with links

6.2.1 - Field PCB
Field PCB Artifacts

6.2.2 - Office PCB
Office PCB Artifacts

6.2.3 - Data Transmission
Data Transmission Artifacts

6.2.4 - Power System
Power System Artifacts

6.2.5 - Enclosure
Enclosure Artifacts

6.2.6 - Pressure Sensor
Pressure Sensor Artifacts

6.2.7 - Data input
Data input Artifact

6.2.8 - Data display

[Data display Artifacts]

[User Manual]

6.3 - Presentation Materials