UCF Senior Design 1

Hurricane shutter protection system with automatic detection and sensing

Department of electrical engineering and computer science

University of central Florida

60 Page Documentation

Group 6

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2. Project Description

Hurricane damage is both inevitable and disastrous, but we believe it can be somewhat mitigated with the right resources. Over the course of human history natural disasters have been a prevalent part of society. Hurricanes specifically have cost society countless lives and 742.1 billion dollars in the last five years alone. This is especially alarming since in the last forty-two years the total cost of damage is 2.155 trillion dollars, making the last five years greater than one third of the overall cost (*Hurricane Costs*). This along with bringing back an aesthetically pleasing part of the home that was lost to modern building techniques and architecture are the reasons why we are passionate about revisiting and reviving old technology with a new twist. This being the hurricane shutter protection system with automatic detection and sensing. This product should not only mitigate the damages of hurricanes and natural disasters alike but also help drive down the ever-growing disaster costs.

2.1 Project Motivation and Goals

The goal with the hurricane shutter system is to be able to produce a product that is relatively cost-effective, reliable, and technologically modern. Starting with the idea that the product needs to be cost-effective, we've noticed a problem in the market where the products that have all of the features that one may want to help in these disastrous situations are put behind a huge paywall that is not even remotely reasonable for the average person. It is because of this that we have such a heavy focus on making this as cost-effective as possible because anyone should be able to feel secure in their home during the disastrous events that require these products. The next major goal would be to create a reliable system that our users can trust will work no matter the conditions. This would entail creating a system that can detect a disastrous event and respond accordingly by closing the shutter doors automatically and setting itself up to be able to be used manually in case of a power loss. Additionally having an LCD display on the housing of the product that displays its current status and any issues that may have arisen will make the usability that much easier for our users. Lastly, to ensure that our product is technologically modern we will utilize modern sensors, location-based weather APIs, and develop our product as an IoT device that way our users can trust they are getting the most up-to-date information as possible while also having the benefits that come with using newer products with more up to date protocols. Delving more into this goal, the sensors will be used to gauge the status of the environment around the housing and determine if any actions need to be taken to protect the location the housing is mounted to, the location-based weather API will allow us to get real-time data from sources besides our own to know if severe weather may soon be present in the area, and having our device connected to the internet will give our users a *hands-on* level of control on the device which will allow for a better sense of security.

2.2 Objectives

The primary objectives of this project are:

- Have the barometer, temperature sensor, and anemometer read / process data in real time
- Have an LCD display on the housing unit that will give the status of the running system
- Have the system communicate with a weather api

- Have a speaker that will be used to notify when the system is performing certain actions
- Have the MCU be able to take in all this information and decide whether to activate / deactivate the shutters

To expand on the basic goals of this project, the shutters need to be able to activate / deactivate in a reasonable amount of time in order to properly prevent damage to the house. The amount of time that one has when preparing for a disastrous event, whether that be an incoming hurricane or a very heavy rain, can range from weeks to just a couple of minutes. It is because of this that one of our main focuses is on ensuring that our product can quickly, and more importantly reliably, activate / deactivate the shuttering system. It is because of this importance that choosing the motor becomes one of the more technical decisions we must make. Continuing this thought process leads to the sensors that we want to be able to gather useful data from in real time in order to help with the decision making for whether the shuttering system needs to activate to protect the house or deactivate if the weather has calmed down. We plan to use a barometer, temperature sensor, and anemometer together in conjunction with a local weather API to provide as much information as possible to the MCU to determine whether to activate or not. To ensure a good level of ease-of-use for the users of this product, we want to include an LCD display on the housing of the shuttering system that will contain easy to view data on the status of the peripherals, battery, and the shuttering system as a whole. Furthermore, expanding on the importance of ease-of-use we also plan to include a speaker on the housing of the system that will notify the user when the system is performing certain functions which would improve safety when the device is activating / deactivating and help with servicing the machine.

The advanced objectives of this project are:

- Create a website / database that stores the data from the system
- Be able to perform remote activations / deactivations on the system through the website

When it comes to our advanced goals or this project, we want to create a website / application to make the experience for the user more streamline and allow them to easily view the status of the shuttering system, see data about how it has been used in the past, and activate / deactivate the device without having to be next to it. Overall, we have developed a rich suite of objectives that when achieved will bring a competitive idea to the market.

Some of the stretch goals that we would like to explore include an IR sensor and remote, plus an application for your phone. The IR sensor would act as a quick way to open and close shutters individually. The phone application would include weather data that is gathered both from the sensors themselves historically and general weather data from online weather organizations that can help give further warning for the user.

2.3 Market Analysis

When comparing our product to some of the competing products in the market, there is a clear gap where we would fit in comfortably. A lot of the products that currently exist in the shuttering system market seem to fall into the category of being incredibly expensive, counterintuitive, or both.

2.3.1 Roll-Up Shutter Design

One of the more popular products on the market currently is the roll-up shutter design. As previously mentioned, a lot of the products that currently exist on the market tend to fall into two categories and this one isn't any different and manages to fall into both. This product is incredibly expensive (costing upwards of tens of thousands of dollars for a whole house setup) and only supports manual operation (no smart technology features implemented, no automation). This type of system can bring more problems than it solves. Excluding the price tag, one of the biggest issues with this popular product is that it only supports manual operation. For many areas that are consistently affected by hurricanes and other similar events the idea of having to take your shutters up and down multiple times a year is one of the most irritating feelings one can have when preparing for a storm and cleaning up after it has passed. Additionally, disastrous events like hurricanes are incredibly unpredictable and because of this some of those that may be affected will not know until it is too late to fully set up their house and if they have a cumbersome system like this that is only manual, they simply will not have enough time to prepare.

2.3.2 Hinge Shutter Design

Another popular product in the market is a hinge design that hangs a massive shutter from the top of the window to the bottom in a sort of clam-shell design. One of the major drawbacks, similar to the previous example, is that it does not have any smart features built into it. Another drawback with this design is that during normal operation (when there is no inclement weather) because of how it is positioned on your window you end up not being able to see out of it due to how it rests on the front of the window. Despite some of the major drawbacks that come with having this type of design, it does have some commendable features that are worth noting. The first being that it is much cheaper compared to the previously mentioned roll-up metal garage door style shuttering system. This bodes well for not only initial cost but maintenance cost as it’s a wooden design so if it is damaged you can quickly and easily hang another one. Another feature that is present in this design is that it has a deadbolt locking system. This works by a set of pins that slot into a hole when the shutter is closed which you can then slide a pin in to ensure that it will not open unless you remove the pin, or the upper hinge mechanism is destroyed during a severe weather event. Lastly, because of how easy it is to use this type of system it is an especially popular choice in the more commonly affected areas such as the Bahamas This subset of cases sees the worst condition compared to Florida: they have the least amount of time to prepare plus they are on an island with limited power and readily available resources. It is because of both these reasons why this solution has become such a popular solution in these areas.

2.3.3 Market Analysis Takeaways

Overall, when we use some of the beneficial features / design choices from the previously mentioned systems in conjunction with our own experience as Floridians (who have gone through many hurricanes and severe weather events) we will be able produce an all-encompassing product that will fit comfortably in its unique position in the shuttering system market. Expanding on some of the features / design choices that we found beneficial for the aforementioned products, we liked the simplicity that came with the single hinge design so we will be also attempting to do something similar but will remove the issue that arises with it of not being able to have direct line of sight out of your window. Additionally, while we do respect the idea of the roll-up garage door design, we cannot help but wish it had smart technology in addition to its manual operation so that it can be activated / deactivated easier. With all the good and bad decisions, we have observed from other products in the market we will take all of them to create a cost-effective, reliable, single hinge design that can properly mitigate the damage that can be caused during severe weather but also make it easy-to-use no matter the circumstance. The product will use all the past products to create something of a comprehensive result and during the course of developing this product we aim to fix all of these issues while also creating a more cost-effective solution that is easy to use and also implements smart technology so that the system can be used / deployed more efficiently.

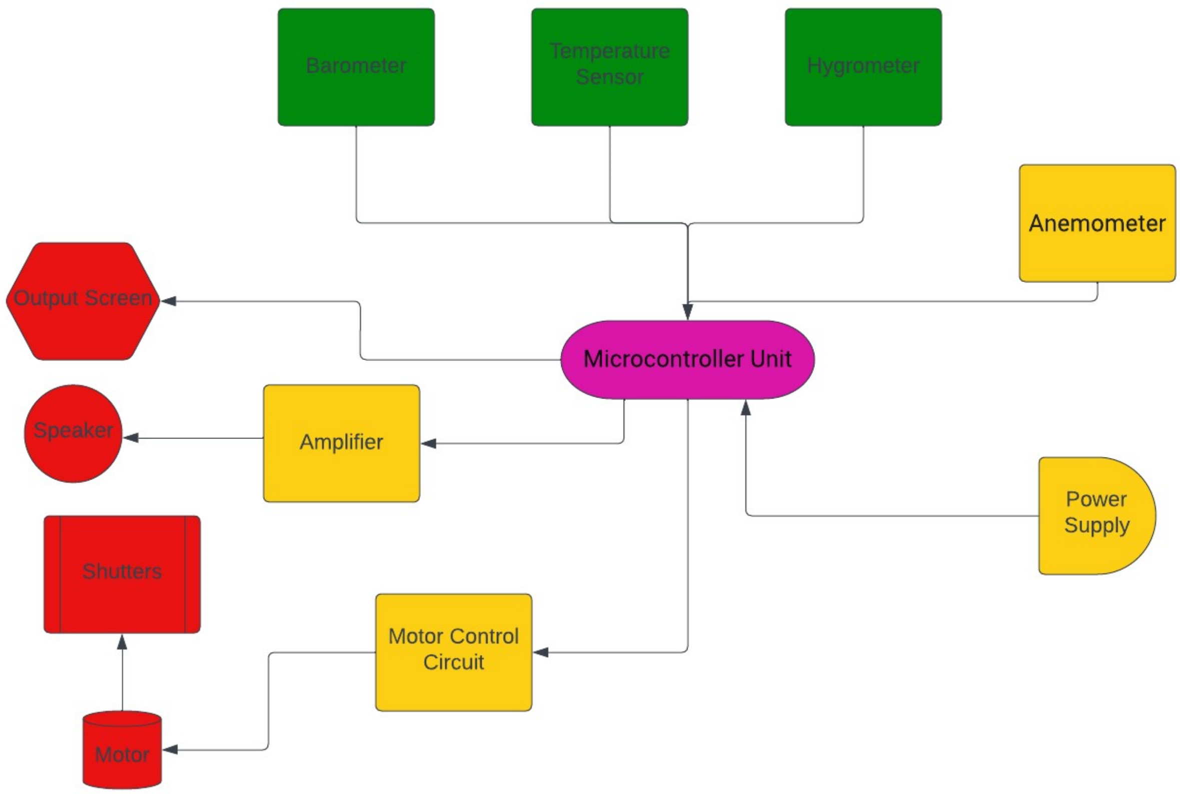
2.4 Hardware Block Diagram and Render

2.5.1 Hardware Block Key

Table 01: Color Key for Hardware Block Diagram		
Color	Primary Member	Secondary Member
Red	Andrew D.	Antonio D.
Green	Antonio D.	Andrew D.
Magenta	Aidan D.	Spencer S.
Yellow	Spencer S.	Aidan D.

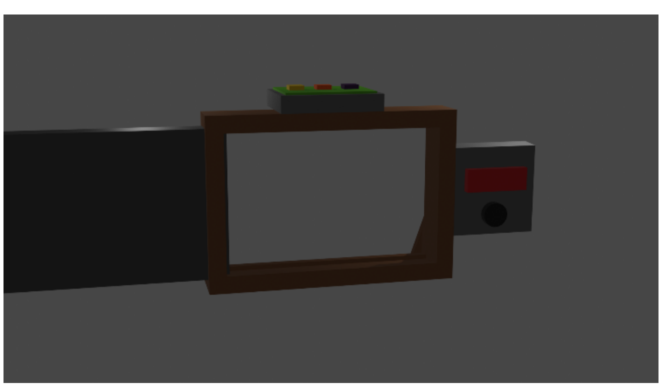
Table 02: Responsibilities for Each Item In Hardware Block Diagram			
Block	Status	Block	Status
Barometer	Research	Shutters	Research
Amplifier	Research	Motor	Research
Temperature Sensor	Research	Open Button	Research
Anemometer	Component Selected	Close Button	Research
Controller circuit	Research	Communication Channel	Research
Output Screen	Research	Smartphone	Acquired
Speaker	Research	IR Sensor	Research
Microcontroller	Research	IR Remote	Research
Power Supply	Component Selected		

2.5.2 Hardware Block Diagram



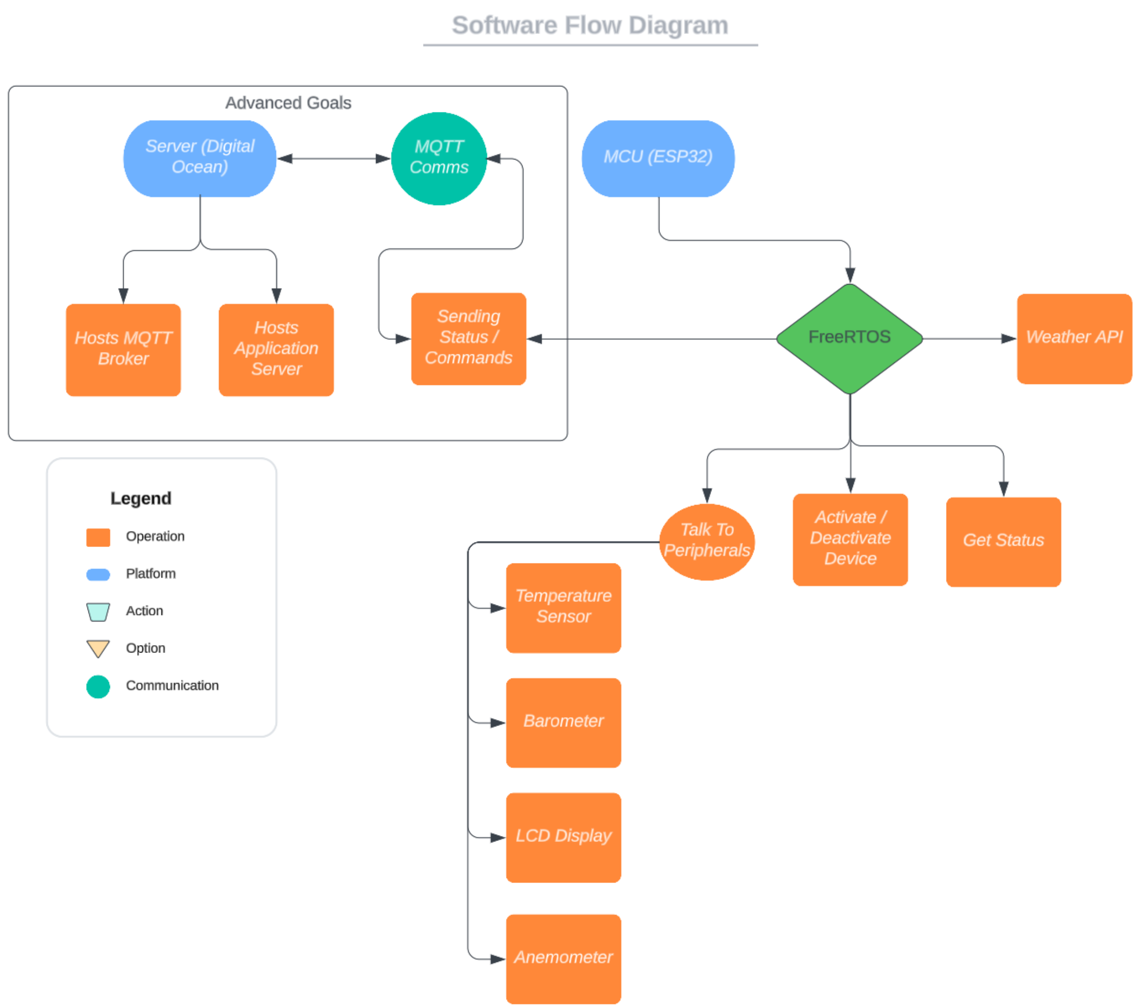
2.5.3 3D Render of System

Front view



Back view

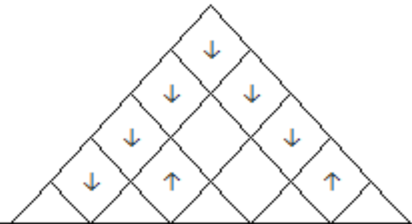
2.5 Software Block Diagram



2.6 Requirement Specifications

Table 03: Requirement Specifications		
Category	**Metric**	**Requirement**
Cost	USD	< $400
Power Consumption	Watts	< 120
Battery Life	Hours	> 12
Installation Time	Hours	< 1
Networking	Wireless Standard	≥ Bluetooth 4.0
	Wireless Standard	≥ WiFi 4
Wireless Range	Feet	> 100
Response Time	Seconds	< 4

2.7 House of Quality



Row #	Column #	1	2	3	4	5
	Customer Requirements / Product Requirements	+ Response time	- Power Consumption	+ Battery Life	- Install Time	- Cost
1	Reliability +	↓	↓↓	↓	↓	↓↓
2	Power Consumption -	↓	↓↓	↑		↓
3	Cost -	↓	↓	↓	↓	↑↑
4	Installation Ease +	↓	↓	↓	↑↑	↓
5	Ease of Use +	↓	↓	↓	↑	↓
	Target	< 4 Seconds	< 120 Watts	> 12 Hours	< 1 Hour	< $400

3. Research

3.1 Relevant Technologies

3.1.1 Hardware Technology Comparison: Shutter Systems

A critical process that all engineering projects need to have done is research. It is always best to have as much information as possible to be used to back up your ideas and overall project. It is also very important to compare similar designs previously done in other projects and/or in industry. This is used to be able to ensure that the current design has not already been created and to help you find areas where there is room for improvement in the current and new designs. In this section we will be looking at other designs that are currently in the industry. We will then be looking at how these designs compare to our own design. We will also be looking at component options that fit the needs of our own design.

There were many different shutter technologies to consider when deciding on the proper design for the new hurricane shutter and detection system. The main technologies on the market today include the exterior rolling shutters, accordion shutters, Bahama shutters and the shaker shutters. Starting with the exterior rolling shutters this is the most modern approach to the system. Physically it looks like a giant mechanic's garage door that rolls down over the desired locations. It's typically made of metal and is renowned for its strength and durability. The problem with the system arises when you take into consideration what a whole house system will cost when installing it in a home and how the exterior of the home will look after it's finished. The whole house systems costs tens of thousands of dollars depending on the home size, and it looks very ugly because the rolls of metal panels are stored in a giant metal box on the outside of the home. A post home installation of this system could also cost you more depending on how well the home was built so overall this system is very costly and ugly to look at. The next technology is the accordion style shutter. This is a little more budget friendly than the rolling shutters, but its downside is that it looks extremely unappealing and has low convenience when using it. Every time you want to close the shutters you have to go outside and pull the accordions shut hoping there isn't any debris in the tracks they ride on. The next technology is the Bahama shutters. They too are a low-cost solution that is better looking in comparison to the accordion or rolling shutters if the home has a tropical theme. They are also meant to be damaged and thrown away afterwards because they are easy to hang and cheap to make. Lastly the shaker shutters. These seem to have a mixture of many of the previous systems all rolled into one. This system is on the most affordable end of the shutter system spectrum. It is more visually appealing than the rolling shutters or the accordion, plus it works with more than just tropical home designs. They have slightly more durability than the Bahama shutters, but they can't take a hit and bounce back as well as the rolling shutters. Overall, we are going to try and incorporate the best aspects of these shutters into our overall design which doesn't exactly fit into any of these categories. Shutters tend to commonly be made of materials such aluminum, steel, polycarbonate or wood. There are also other options by brand such as Kevlar based.

Aluminum shutters may be the most frequently used option for hurricane shutters. It features natural corrosion resistance which makes it ideal for long term use. This also contributes to less maintenance and parts replacement as degradation is minimal. Aluminum also offers similar strength compared to other metals but is lighter in weight when compared. This makes for less stress on other components used in the system and easier for installation and repair. Aluminum also has the benefit of being one of the easier options to handle and form to make varying styles such as accordion and rolling shutters.

Steel shutters are a great option as far as strength. They are a much stronger material when compared to aluminum, polycarbonate, and plastic options. This offers better protection from projectiles but does also come with downsides. Heavier metals such as steel are just that, heavier. This adds more overall weight to the shutters and requires more robust installation components. Steel shutters are also more prone to corrosion. They are usually coated with anti-corrosive material, but this increases maintenance cost for the overall system. This type of material can typically be seen in storm panels and roll-down shutters.

Polycarbonate shutters are essentially an impact resistant plastic material. They are usually clear to allow for sunlight to come through and can be arranged in different form factors such as in sheets or accordion style. They can even be bought to cut to desired size. This option is durable but offers low protection when compared to the metal options. This, however, is very lightweight for easy handling and installation and relatively low in cost.

Wood offers good durability at lost cost. It also allows for easy handling, maintenance, and repair. This material option is also the most aesthetically pleasing of all the options available. It can be arranged in many different styles and customized to match the home. Wood is also easily available which helps reduce the cost of materials when installing or repairing these shutters. This material is typically used in Bahama and Shaker style shutters. Our design will be using a shutter made of wood.

Our shutter design aims to take the durability of the rolling shutters, the looks of the shaker shutters and the unique designs and repairability of the Bahama and accordion style shutters. As seen in the three dimensions models in a previous section our shutter will come from the side and slide in front of the window for optimal protection. This action will be very durable because of the thickness of the sliding mechanism that will also be motorized like the rolling shutters. The looks of the system will be inline of the shaker shutters or Bahama style in the sense that everything will be hidden away in the wall until the need arises for the system to deploy. Lastly the repairability the idea is that with one piece sliding back and forth if it takes massive damage that deems it inoperable you could somewhat easily remove the damage panel and slide in a new one. The last aspect is the unique design, there aren't many designs exactly like ours, so our goal is to bring a new design into the space that does the job of all the previous ones.

3.1.1.1 Hardware Technology Comparison: Sliding/Accordion System

Accordion shutters are one of a few design options used for hurricane home protection. This design is comparable to ours but has noticeable differences. This design consists of a framing that is installed around the window or door. The framing is usually made of aluminum and integrates the track that the shutter will be sliding within. The shutter material itself tends to usually be made of a Kevlar or aluminum that is arranged as an accordion. This allows it to be pulled from each side stretching across the desired area of protection and locks in the middle with a latch. Using this style shutter requires physically coming out and manually opening, closing, and latching the shutters before the storm or hurricane during preparations. This option is usually not the most visually appealing as it requires all of the components to be installed on the outside, around the area that is being protected. Due to the ease of the design and its functionality it is one of the more cost-effective options as well. One area this style shutter does better than other styles is the fact that it can be customized to wrap around curved edges and windows. Another benefit to them is that they are not powered or consume any electricity so there is no cost to operate them. They also require practically no maintenance and are more DIY friendly.

3.1.1.2 Hardware Technology Comparison: Motorized Roll down System

There are many motorized roll-down (or roll-up) shutters in the industry. Most of which use the same basic design to function with certain variations or features depending on the brand. For the most part they all consist of a framing around a window, door, or opening. The shutter itself is usually made of aluminum strips that are linked together so that it can be rolled up and down when needed. Though other options as far as materials are available as well such as steel or Kevlar. The variations between designs are mostly on the in the motor location, size and power use, and activation of shutters.

For location the electric motor can be mounted on the bottom below the window however, on most designs it is mounted on top above the window. Almost always they will be located next to the roller that stores the shutter itself. There are some designs that use a chain, gear, or combination of the two if spacing is limited and the motor is needed to be mounted elsewhere. A good example would be for windows in corners or multiple windows in close proximity to each other. In those cases, the motor can be placed on the other side of the window inside the house.

Sizing of the motor mostly depends on the sizing of the shutter itself. The smaller the shutters such as ones used on windows and door the smaller the motor. This is in comparison to the larger shutters used on larger windows or patios as examples that would need a larger motor. This is all due to the amount of torque needed for varying weights of the shutter based on size and the material it is made of. The sizing of the motors also plays a large role in the power consumption of them as well. Most motors used for shutters can range around 100W to 500W for windows and some for larger areas can consume 1200W or more of power. Choosing the right motor is important for this setup and power usage can quickly stack up as more than one will be needed to protect all windows of a home or any building. Outside if that power delivery to these motors could increase installation cost in certain cases. Also there needs to be a backup power supply, if the power were to go out these will not have any function. It is recommended that this system be coupled with a solar panel system or comparable system that has battery storage backup to run on during such an event. When planning to have these install and wanting usage during a power outage these added accessories add to the installation difficulty and quickly stacking overall cost higher and higher.

Options for controlling the movement of the shutters are something worth considering as well with this style of shutter. Some can be controlled through a control switch installed at a specific location that can be activated when needed. A step above just pushing a button would be a control hub that can also be installed. This can add additional features and make controlling the shutters more aesthetically pleasing. There is however an option above that to control them via smart phone application. This option communicates with a module installed within the home. With the smart phone activation options there can be mor control options such as smart shutter options that allow the system to be controlled via RTS, Zigbee, Google Assistant, and Amazon Alexa. The more advanced systems that incorporate smart home controls usually also include a feature called Sun control or Sun / Shade Control. This feature allows for the shutters to be closed to block out sunlight. This can be used for comfort when low light conditions are needed. It can also be used to help with the air conditioning system of a home. This is done by closing the shutters on the side of the home under direct sunlight to help prevent heating through the windows to help keep the interior cool.

Visually the roll-down shutter option does not stand out as much as the accordion option. It does, however, require a large unit to be installed above or below each window or desired protected opening. This design also requires more complicated hardware installation. And depending on the option purchased networking installation may be required for the Smart Home functionalities. One of the larger drawbacks to this type of system is the cost of components and cost of installation. Another drawback this system has over others is the maintenance and upkeep required to keep them operational. Thorough cleaning as part of maintenance also requires more work compared to other options.

3.1.1.3 Hardware Technology Comparison: Bahama / Shaker System

Bahama / Shaker shutters are the most economical and user-friendly option. They are installed with hinges using the existing window framing on the side or top of windows. They are normally located on the sides of or right over the window and can be opened and closed manually. These tend to be the most inexpensive and easiest option to install. They generally also look the nicest aesthetically as there isn't much additional as far as components to stand out or to try to blend into its surroundings. These also need to be manually opened and closed in preparation for a storm similar to the accordion style. These shutters can be made from various materials as there is no direct standard on what material to use and may even be installed for style over function, serving little to no functional protection from projectiles in strong hurricane winds. This option offers a comparable amount of protection but are the most cost effective, visually appealing and customizable, and easiest to maintain.

Table 04: Technology Comparison of Shuttering Types (duplicate)

	Accordion	Motorized Roll-Down	Hinged	Our Design
Cost	Low	High	Low	Low
Ease of Installation	Mid	Low	High	Low
Maintenance	Low	High	Low	Mid
Power consumption	Low	High	Low	Mid

3.1.2 Hardware Technology Comparison: Display

Overall, there are many types of displays that could be used to achieve the goal of having a display that can accurately and reliably display the information provided to it. It also needs to fit within the parameters of the project including but not limited to size, shape, power usage software package compatibility and micro controller compatibility. The most popular types of display that are typically used with micro controllers are Multi segment LED displays, LCD (liquid crystal displays), OLED (organic light emitting diode display), and ePaper (electronic paper). Each of these technologies have somewhat distinct features that will help in the decision-making process when trying to decide on the proper technology to choose for the hurricane window shutter. The first technology in consideration is multi segment LED displays. They have been around for one hundred and twenty-six years and have been a staple of most basic consumer electronics ever since. One of the first advantages that come with them are their basic design which leads to its massive and wide-ranging compatibility with different types of microcontrollers. Plus, its typical communication interface is SPI and I2C which are two examples of communication interfaces that could fit our project due to most microprocessors having those as their main serial interfaces. The next technology under consideration is LCD or Liquid crystal display. This technology is slightly newer than the previous technology, the seven-segment display, and it has much better features. LCD offers a much more vibrant and clearer image as well as not being limited to large segments; it can create detailed images within its pixel's sizes. This technology also uses popular communication interfaces including SPI, I2C LVDS and MIPI. Lastly, they on average come in larger sizes that have larger diversity when being implemented. The next technology is OLED, which is even newer than both LCD and Segment displays. Despite this, OLED comes with many different features compared to them. The first being a better pixel density as well as using SPI as its main communication interface. The downsides with this are that it requires more power to drive the higher pixel density and that the typical SPI type will require four wires to properly display its full capabilities. The last technology is ePaper. This is the newest technology of the group. It has some positive aspects like being ultra-low power and being very simple to operate. But its purpose is to be set and left alone and for our project this isn't the goal. Plus, it also needs to be powered when flashing the data onto the device.

After much consideration, the technology that was selected was LCD. It offers the best connection and communication interfaces that not only works with our projected microprocessor but is familiar to our team, meaning that everyone can has a reasonable understanding of it. On top of that it doesn't use too much power and can be easily powered by the power supply we are designing. To expand on the differences mentioned previously, the below table will delve into the differences between the different display technologies.

Table 05: Comparison of Display Options				
Type	Segment	LCD	OLED	ePaper
Low Power consumption	X	X		X
MCU compatibility	X	X		
Character Capabilities		X	X	
Pixel density, color, accuracy		X	X	

3.1.3 Hardware Technology Comparison: Speaker and Amplifier

Many different technologies can be considered when looking into choosing a speaker and amplifier combination for our application. These include at the broadest level sub-woofers, midrange, and tweeters. The first technology to compare is the sub-woofer. The ideal frequency for sub-woofers is twenty to two hundred hertz which makes the main purpose for a speaker like this being to accurately reproduce low frequency sounds. For our application this is far from what we need, we will most likely be using a mid-range buzzing sound to indicate different aspects of the device. It also uses lots of power, which isn't optimal since our system will be working with a limited power source. The next technology that needs to be discussed is the tweeter. These speakers are aimed for frequencies in the range of two thousand hertz to twenty thousand hertz. These are less power demanding than sub woofers. Despite these benefits, this is also not exactly what the perfect speaker is for our application. We do want an audible buzz but not something with that much frequency. Additionally, there is a limited supply of speakers in this range that are affordable and interface well with our microcontroller. The last technology and likely the best one is the mid-range speaker. This speaker struggles to get to the lowest frequencies and the highest frequencies. However, the advantage here is that it's an all-around powerhouse when it comes to faithfully reproducing sound as well as having a typical use case for microcontrollers. It also doesn't use as much power as the sub-woofer and tweeter. Plus, the impedance is reasonable enough to be able to use a small amplifying circuit and get the intended output.

A sub-level of technology that needs to be explored is the amplifier type. The main two that we will consider are low voltage audio amplifiers and high voltage audio amplifiers. The main difference is in their names and applications. The low voltage amplifier is used in low voltage applications. While the high voltage amplifier is used in high voltage applications. An area that the low amplification wins out is that it is within our price range while also having better distortion levels compared to its high voltage counterparts.

After looking into the various technologies and the pros and cons that come with each, the technologies that we ended up choosing are the midrange speaker with a low voltage amplifier circuit. This combination will be appropriate for the circuit, has low distortion will accurately reproduce any sound we want within reason and most importantly interface properly with our microcontroller. In the below table we will expand upon the technologies we mentioned previously and compare them to one another.

Table 06: Comparison of Low and High Voltage Amplifier		
Type	High Voltage	Low Voltage
High Voltage application	X	
Low Voltage application		X
Application compatible		X

Table 07: Comparison of Speaker Options			
Type	Tweeter	Mid-range	Sub-woofer
Desired frequency range		X	

Gain	X		X
Cost		X	
Low power consumption	X	X	

3.1.4 Hardware Technology Comparison: Motors and Controllers

When considering a type of motor there are a lot to choose from. These include AC brushless motors, DC brushed motors, DC brushless motors, direct drive motor, linear motors, servo motors, and stepper motors. AC brushless motors are a very popular type of motor to use in a wide range of scenarios. They are used in industries like food production, medical, oil refining, explosive liquid and so many more. They are best known for three properties long lasting, quiet and reliable motion. Next is DC brushed motors. They are best used in scenarios when you don't need to control the speed of the motor and when an electronic control circuit isn't needed. Next is DC brushless motors. Their common uses case are tools, toys, and household appliances. This is a good motor for our use case seeing as it has versatility with its application and a clear use in power limited areas as well as high torque applications. The next technology is a direct drive motor. Its applications include elevators and industrial shredders. They can also be used to target quiet operations. This motor is very versatile, it has strength and reliability. The direct drive motors are very power efficient and have great power density compared to the previous motors. After that the next motor technology is linear motors, they have great use in industrial automation because of their high precision, velocity, and force. This makes them perfect for robotic applications since they are able to make consistent repeatable actions. Next is servo motors, these are most common in use today in changing how fast your car is going. This is done when you press on the gas pedal and a servo motor is sent the signal to adjust your throttle. It can also be used in RC toys like planes, trains, and trucks. The main advantage of a servo motor is that it has great precision and can adjust based on the load. The disadvantage is that it can cost a lot and maintenance also costs a lot. Lastly, stepper motors are a subset of DC motors that have extreme precision because of how they are built. They are also unique in the fact that it takes a digital input that gives it the precise starting and stopping that it's known for

The subset in this is the motor controller. There are four basic types that go with the previously mentioned motor types. They include AC DC servo and stepper. AC motor controllers typically aim to regulate the speed and torque of the motor. DC controllers typically are used to control the motors speed and torque again. Servo controllers also controls speed and torque but this time they also can control position. Lastly stepper motor controllers control position speed and torque but this type needs to specifically tuned with the application in mind.

Table 08: Comparison of Motor Controller Technologies

Type	AC Controller	DC Controller	Servo Controller	Stepper Controller
Application specific	X	X	X	X
Cost		X		
Power type		X	X	X

Table 09: Comparison of Motor Type Technologies

Type	AC Brushless	DC Brushed	DC Brushless	Direct Drive	Linear	Servo	Stepper
Cost		X	X				
Durability	X		X				X
Sound	X					X	X
Strength			X	X	X	X	X
Precision					X	X	
Maintenance			X				
Power to run				X			

3.1.5 Hardware Technology Comparison: Barometer

When searching for the best barometer for our application we first needed to understand what a barometer is and why it is necessary for our project. A Barometer is a device that is used for measuring atmospheric pressure. They are mainly used in weather forecasting and to determine altitude. In our application we will be using it for weather forecasting to be able to detect if weather conditions are those that are common before and during a hurricane. This will be one of a few inputs needed to measure and meet thresholds for the shutter to activate and deactivate.

Traditionally barometers exclusively relied on mechanical means, employing either Mercury or Aneroid Barometers. These would manipulate atmospheric pressure to move mercury or specialized fluid causing it to ascend or descend within a gauge, this would provide an indication of atmospheric pressure levels. While this approach was admirable it will not work in today's standards which rely heavily on application using a microcontroller. Given the constraints of our microcontroller-driven system, relying on the mechanical movement of fluids becomes impractical. There are however some digital based options that will easily take place of the mechanical version and can excel in many areas in comparison with additional features.

Digital MEMs Barometer:

Digital MEMs type of barometer uses a very small integrated circuit that combines mechanical and electronic elements to sense pressure. This combination is called a Micro-electromechanical (MEMs) sensor. Commonly these sensors are either capacitive or piezoresistive in how they function and vary output. These devices are used in many applications such as in airplanes, weather stations, and smart devices. And are widely used in many industries. MEMs barometers can range in accuracy between 1 to 5 percent. This type is usually packaged in more complex components but alone can cost as low as $4.

Precision Digital Barometer:

MEMs barometers must be calibrated to ensure accurate readings for their application. Precision digital barometers still function using MEMs but are held at a much higher standard and calibrated to be extremely accurate. These are used in areas where high accuracy is important such as in clean rooms or meteorological weather stations. They can even be used to calibrate other sensors. This type can have an accuracy of up to .008 percent. This, however, does typically come with a much higher cost per sensor.

In our design our design we will be opting to use a Digital MEMs sensor. This was chosen because the extremely high accurate reading of the Precision Digital Barometer is just not needed when measuring atmospheric pressure as an input for hurricane signaling. The Digital MEMs also benefit over the other in cost. This will help keep development and the final product cost lower while keeping functionally accurate results.

Table 10: Comparison of Various Barometer Technolgoies

	Mercury / Aneroid	Digital MEMs	Precision Digital
Digital output		**x**	**x**
Accuracy	**x**	**x**	**x**
Cost		**x**	

3.1.6 Hardware Technology Comparison: Anemometer

Anemometer:

One of the critical engineering requirements for our IOT smart home hurricane shutter project is the ability for the device to autonomously sense the wind speed and respond accordingly by closing the shutter if wind speed is hazardous and all other criteria is met. The proper way to measure the windspeed is through an anemometer. There are three dominant technologies in use for anemometry, a hot-wire anemometer, vane anemometer, and cup anemometer.

Hot-wire Anemometer:

The hot wire Anemometer works by connecting two probes across a wire that has a current moving through it. The wind speed is indirectly measured by measuring the voltage/current or some other parameter of the wire that changes with temperature. Hot wire anemometers are best used when the speed of the fluid being measured (air in this case) is relatively constant and the temperature doesn't fluctuate much either. [S1][S2]

Vane anemometer:

The vane anemometer can typically be found as portable handheld devices. The vane anemometer has a propeller on top of the device that senses the wind speed. In order to properly use the vane anemometer, the user must face the propeller directly in the direction of the wind to get an accurate measurement.

Cup Anemometer:

The cup anemometer is a stereotypical wind measuring device. The cup anemometer is typically a cylindrical base with a free spinning rotor on top with spokes tipped with cups to catch the wind. The vane anemometer is typically used in meteorological applications and remains stationary.

Table 11: Summary of Anemometer Technology			
	Hot-Wire	Vane	Cup
Application	Scientific/Industrial	Mobile	Meteorological
Size	Sub-Hand-Held	Hand-held	~1ft^3
Complexity	Depends heavily on software to interpret sensor data.	Complex, requiring wind direction to be known	Simple, emplace device in open area. Digital or analog.

The best technology to sense the windspeed is cup anemometer since the device is stationary and the direction of wind does not need to be known. The fact that the vane anemometer requires the device to be pointed in the direction that the wind is coming from adds unnecessary cost and complexity to the design. The hot-wire anemometer is not suited for winds caused by weather because the direction and speed of the wind in a storm can change rapidly and be unpredictable.

3.1.7 Hardware Technology Comparison: Battery Chemistry

The choice to power this project with a battery was made as one of the engineering requirements. The window shutter is required to store enough power in a battery to operate even in the event of a blackout. Were our device to be mass produced, the device would operate on the main power supply of the house, only switching to battery power during a grid power failure. Additionally, working with 120VAC is out of the scope of our prototype.

When choosing battery technology there are several considerations including: chemistry, energy, power, size, and price. The battery must be rechargeable so that during the debug and demonstration of the final product we aren't required to purchase a large number of batteries. Since the batteries are rechargeable the long term costs will be lower. Another reason the batteries should be rechargeable is so that the end user is not burdened with the nuisance of having to replace the batteries in their shutter system. There are dozens of different battery chemistries that have different advantages and disadvantages. I am limiting the selection to the chemistries shown below as these chemistries are the most common, cost effective, and available.

Lithium-Ion (Li-ion):

Li-Ion batteries are rigid rechargeable batteries. The electrolyte within a Li-Ion battery is liquid. Lithium Ion is one of the most common battery technologies used today because of their high energy density, lack of memory effect, high power delivery, and slow self-discharge rate. One of the major downsides of Li-Ion batteries is their volatility. Li-ion batteries have been known to be flammable and even combust. Lithium Ion batteries and their derivatives all require a battery management system (BMS) to ensure the battery is stable and does not suffer from runaway thermal effects leading to overheating and fire hazards. [S4] [S5]

Lithium-Polymer (Li-Po):

Li-Po batteries are different to Li-Ion batteries by having a gel like electrolyte instead of the liquid found in the Li-ion. The Li-Po battery is less energy dense, and more costly than the Li-ion battery. The main feature of the Li-Po is the batteries typically are packaged in a small flexible "pouch" instead of a rigid cell. Li-Po batteries also do not suffer from the memory effect which causes a loss in total capacity when only partially charging and discharging. [S4] [S6]

Lithium-Iron-Phosphate (LiFePo4):

LiFePo4 batteries are a subset of lithium ion batteries. The main benefit of LiFePo4 is stability. LiFePo4 batteries are less prone to thermal runaway like Li-ion chemistry. The tradeoff for the added stability of LiFePo4 batteries is their reduced energy density and a slightly higher cost. LifePo4 batteries are typically used in stationary applications where space is not a major concern such as a backup power system in a house. [S7]

Nickel-Metal-Hydride (NiMH):

NiMH battery chemistry is superior to Lithium chemistry only in price. NiMH batteries are simpler and cheaper to manufacture leading to a lower cost to the consumer. NiMH batteries also do not require battery management systems (BMS), another BOM saver. The tradeoff for a lower cost is less energy density. The NiMH battery is much heavier for the same amount of energy which is why lithium chemistry dominates the mobile electronics market. Additionally, the voltage provided by a NiMH cell is less than half of the voltage of a lithium chemistry meaning that a NiMH cell will typically deliver less than half the power of a comparable lithium battery. [S8]

Table 12: Summary of Battery Chemistry

	Lithium Ion	Lithium Polymer	Lithium Iron Phosphate	Nickel Metal Hydride
Cell Voltage	3.7	3.7	3.2	1.2
Specific Energy(	100-265	100-158	100-120	30-80
Energy Density	185-220	185-220	135-150	140-300

Power Density	245-430	245-430	~200	450-550
Self-Discharge rate	0.3	0.3	0.3	~25%
C-rating	1	1	1	
Memory effect	No	No	No	Yes

Note: The values listed above are only typical values. There can be a large variation in the values presented in this table based on the material quality, form factor, temperature, environment, and the manufacturing process utilized. [S8] [S9] [S9][S10][S11][S12][S13]

The battery chemistry chosen to supply power in this project is lithium iron phosphate. LiFePo4 offers an effective compromise between stability and energy density. Choosing the LiFePo4 chemistry means giving up some of the energy and power that Li-ion provides but is safer from suffering thermal runaway effects that could be costly when used to power the window shutter during a blackout. LiFePo4 is also superior to NiMH in all ways except cost and simplicity (LiFePo4 requires a battery management system). LiFePo4 offers the best compromise of all the battery technologies discussed for this project.

3.1.8 Hardware Technology Comparison: Voltage Regulators

Voltage regulators:

The sensors and the microcontroller all require a stable 3.3V or 5V voltage source to function. In order to achieve these stable voltage supplies it is best practice to use a voltage regulator IC. The two dominant types of voltage regulator are switching regulator and linear regulator. A discussion of each type can be found below.

Linear regulator:

A linear regulator regulates voltage by dissipating extra power as heat. A linear regulator's efficiency is directly proportional to the difference between the supply voltage and the output voltage of the regulator. For a large supply voltage, the efficiency of the linear regulator would be very poor, and the regulator may need a heat sink which would add to the BOM. A linear regulator may be useful in a low power application where the wasted power would be negligible or if the dropout of the regulator is low enough that the wasted power is small. A linear regulator is also useful in applications where noise is a concern since there is no switching involved. [S3]

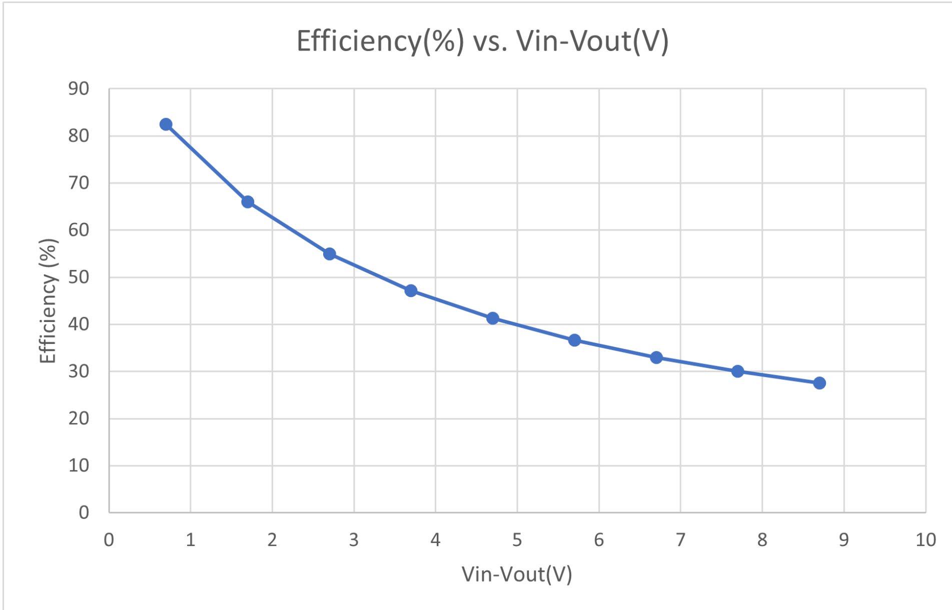


Figure 01: efficiency of a linear regulator vs the supply voltage and output voltage.

Switching regulator:

A switching regulator is preferred when there is a need for high efficiency. The switching regulator relies on switching to maintain a stable average voltage and energy storage elements such as inductors and capacitors to smooth the voltage ripple to DC. The switching regulator can be 85%-90% efficient independent of the input and output voltage. A switching regulator can also provide a voltage higher than the supply voltage whereas a linear regulator can only provide a voltage less than the supply voltage. [S3]

Table 13: Summary of Voltage Regulator Technology		
	Switching	Linear
Efficiency	>85%	<30% (12V to 3.3V)
Complexity	More complex	Simple
Noise	Noisy	High SNR
Current	Can deliver large current	The more current the hotter the regulator will get.

The automatic window shutter is designed to operate on battery power so that in the event of a power outage the windows will still operate so the system should be as efficient as possible to maximize longevity. Additionally, the motors, speaker, and sensors may require a large peak in current for short periods. There is a risk of the linear regulators getting too hot and failing when the load is particularly heavy. The obvious choice for voltage regulators is switching regulators. In our case there is a need for a higher and a lower than supplied voltage to power our sensors and microcontroller.

3.1.9 Hardware Technology Comparison: Temperature sensor

Temperature sensors are used in many applications in many different industries. Being able to know the temperature of many different things is something that most of us take for granted every day. Today just about everything is done electronically and temperature sensing is no different. Temperature sensors are used in areas such as automotive, food prep., and weather forecasting. Today the four most common types of temperature sensors used in electronic are:

- Thermocouples
- Thermistors
- Resistive Temperature Detectors (RTDs)
- Semiconductor based integrated circuits.

Thermocouples:

This type is possibly the most common type of temperature sensor. Thermocouples can operate within a wide range of temperatures depending on the application. This is due to the many variations of metals that can be used for this type to operate. They generate a voltage difference between two substances, requiring no external power source to run them. They are also accurate and have quick response times. Although this type seems desirable due to its efficiency it does have drawbacks. One if the downfall of this type is its low voltage output. This output is what is relied on for a reading temperature. If the equipment used does not have the ability to pick of the voltage difference, then it will either not work or need amplification of the voltage. This can complicate designs further than needed. Due to its low voltage output it is also susceptible to external noise that can distort sensor readings through longer wires.

Thermistors:

This type of sensor can commonly be used in a two-wire configuration allowing for easier design. They are normally made of a polymer or ceramic material which aids in keeping cost low. As temperature changes the resistive properties change of the material and the change is measured and correlated with a specific temperature. This resistive change, however, is not linear and requires some correction to get a proper reading. This makes this option less accurate as resistance reading can vary at specific temperatures. Thermistors also do not provide the fastest response time as it relies on heat transfer to the sensor itself to give a result. This option is less susceptible to eternal signal noise and its output is reliant on the input given by the micro controller. The output and input reliance also means that current must be provided to it for it to function.

Resistance Temperature Detector (RTD):

The RTD functions very similarly to the thermistor, only it uses metals with well-defined resistive vs. temperature characteristics such as Platinum. Because of this the resistive change due to temperature change is very close to linear. This provides higher accuracy and consistency over thermistors. They also come in two, three, and 4 wire applications each having different levels of accuracy and resistive properties to fit design needs. This option does come at a higher cost due to the metals used. Also, RTDs do not offer the fastest response time for the same reason that thermistors do not. It also must have a current supply to it to properly work.

Semiconductor based:

Semiconductor based ICs come in two different styles. Remote digital temperature sensor and local temperature sensor. Remote measures temperature of an external transistor and local measures the die temperature both using physical properties of transistors. Both types can use digital or analog outputs. Digital outputs can be read in different formats such as:

- I^2C
- SMBus
- 1-Wire®
- Serial Peripheral Interface (SPI)

Analog outputs can be either current or voltage based similar to the previous mentioned options above combined. Response times can be similar to the thermistor and RTD but with higher accuracy. This option also can be seen combined with other components making it a smaller form factor. This option also requires current going to it and depending on configuration will need more connections and a communication protocol to receive readings.

In our design we have opted to use a semiconductor bases temperature sensor. It can be found incorporated in the barometer sensor which saves design space and cost. It also will fit well with our sensing module as we already have a communication protocol setup for reading the other sensors. Quick temperature response time is not needed and operating temperature ranges available fit within our design needs.

Table 15: Temperature Sensor Technology Types				
	Thermocouple	Thermistors	RTD	Semiconductor based
Cost	High	Low	Mid	Low
Accuracy	High	Low	Mid	Mid
Communication	ADC/Voltage	ADC/Resistance	ADC/Resistance	• I²C • SMBus • 1-Wire® •SPI
Efficiency	High	Low	Low	Mid

3.1.10 Hardware Technology Comparison: Humidity sensor

Humidity sensors are a very important and widely used in a number of industries such as in consumer electronics, biomedical, and weather forecasting. Humidity measures the amount of moisture in the air and is usually displayed in percentages. This percentage comes from Absolute Humidity (AH) which is the mass of water vapor to the volume of air. To measure this electronically there are 3 main sensor types within the humidity sensor category. These types are as follows:

• Capacitive humidity sensors

• Resistive Humidity Sensors

• Thermal Conductivity Humidity Sensors

To choose the right type of sensor for our project we looked at the pros and cons of these types of sensors and found the following.

Capacitive humidity sensors:

These types of sensors are based on capacitive effects where the dielectric material changes with the change of humidity. This option is the most basic type of humidity sensor and is typically used in applications where cost, robustness, and size are important design constraints. This type of humidity sensor comes with some advantages. They are rigid and can provide consistent stable results over extended periods of time. They are also sensitive enough to detect a wide range of relative humidity which makes them suitable for many applications. Another benefit of them is that they have a output voltage that is near linear with allows them to give fairly accurate measurement readings. All of these advantages do come with a downside. This type of sensor suffers from signal interference or degradation the further the sensor is from its reading source (microcontroller).

Resistive Humidity Sensors:

This type of humidity sensor works similarly to the capacity sensor only it relies on varying resistance instead of capacitance. This is done by using materials that have relatively low resistivity. These resistive properties change in relation to changes in humidity. This type has a wider range of advantages. On advantage it cost, this type tends to be lower in cost to implement. They can also be found in small sizes allowing for better placement in designs requiring smaller footprints. Another advantage is that unlike the capacitive type, the distance between the sensor and the signal circuit can be larger as signal is less susceptible to interference. The last advantage of this type is that it is highly interchangeable. Resistive type sensors have no calibration standards allowing them to be replaced easily. Though the advantages for this type of sensor make it suitable for many applications there are also downsides to them as well. One disadvantage is that resistive humidity sensors are sensitive to chemical vapors and other contaminants that can cause false readings or damage. Another disadvantage is that output results can shift if it is being used with water soluble products. These disadvantages can completely outweigh the advantages in specific applications.

Thermal Conductivity Humidity Sensors:

Thermal conductivity humidity sensors are also known as Absolute Humidity sensors because this type measures absolute humidity. This type of sensor measures the thermal conductivity of dry air and of air with water vapor and this difference in conductivity can be related to absolute humidity. This sensor is the most complicated in setup, relying on a combination of two thermistors. This setup allows this sensor to have advantages unlike the others. This type of sensor is very durable. It can be used in applications that are in high temperature environments. It can also be used in highly corrosive environments as well. And while it is able to handle harsher environments, another advantage it has over the other types is that it gives higher quality measurement reading. With these advantages mentioned there is one main disadvantage to this type of sensor. Reading measurements can be affected if the sensor is exposed to any gas with thermal properties that are different from that of Nitrogen. This disadvantage can be very application specific.

In our design we will be using a resistive humidity sensor. When looking at factors such as size, accuracy, cost, circuit complexity, and output. The resistive humidity sensor matches our design criteria perfectly. It can be easily implemented at a low cost. It also be easily replaced should another option be needed or damage to the sensor require replacement. It is also found integrated in other sensors and if need be, can be easily sourced externally to explore other design options.

Table 16: Humidity Sensor Type Comparison

	Capacitive humidity sensors	Resistive Humidity Sensors	Thermal Conductivity Humidity Sensors
Cost		**X**	
Size		**X**	
Accuracy	**X**		**X**
Durability		**X**	**X**
Measurement Range	**X**		
Signal Strength		**X**	
Ease of use		**X**	

3.1.11 Software Technology Comparison: Communications

Determining how we wanted our system to be able to communicate with the outside world led us into the rabbit while of wireless communications and everything that came with it. When determining which wireless communication(s) would work the best for our system the major factors that it came down to were range, reliability, and data transfer rates. Considering these factors, it led us to narrowing in on WiFi, radio frequency, and Bluetooth. In order to properly demonstrate what each communication method offers our system, the below paragraphs will each elaborate on individual method and discuss what it will offer the system.

One of the most common forms of wireless communications that most people are quite familiar with is that of WiFi. Usually implemented for local area networking, it brings the vast advantages of high data transfer rates, wide range, and multiple device connectivity. These combined would offer our system a vast range of benefits and allow it to be easily accessible and allow us to not have to worry about range from indoors to outdoors. Despite this, when it comes to the disadvantages that come with WiFi those revolve around it having a higher power consumption (comparative to other options we are looking into) and being susceptible to interference from other devices/networks.

Another form of wireless communication that could be a great fit for our application is that of radio frequency. Radio frequency would allow our system to utilize popular protocols, such as Zigbee, to create a system that is able to communicate with external devices over a long range and with a low power consumption (comparative to other options we are looking into). Comparative to other options, a few of the ways that radio frequency can instead detriment our system revolves around its low data transfer rates and susceptibility to other wireless devices, electrical equipment, and environmental factors.

The last wireless communication that we would work well for our system is that of Bluetooth. Bluetooth, similar to radio frequency, would offer us low power consumption (comparative to other options we are looking into) in addition to also offering great short-range communication. However, the downsides that Bluetooth would bring us its lack of range (comparative to other options we are looking into) and its low data transfer rates.

When taking in all the advantages and disadvantages that are brough with each of the listed wireless communication methods, we have decided to go with implementing WiFi for our external communication with our server/website (for reaching one of our advanced goal) and Bluetooth for manual activations/deactivations.

3.1.12 Software Technology Comparison: Weather API

In conjunction with the multiple sensors that our system will be equipped with, we will also be hooking our system up to an external weather API to validate any results we gain from the sensors and retrieve any information for weather events that will be occurring in the near future. There are various free options that are available to the general public and in the below paragraphs we will discuss the most promising options.

The most popular weather API that is available to the general public for free is WeatherAPI due to the vast number of features that are offered under the free plan and partnership with several governments and meteorological agencies. For our application, a couple of the most useful features that come with this API are its allotment of one million requests per month (~16666 requests per day) and weather alerts. This option does not come with many downsides, however, compared to the alternative that we are looking into, it does not have an as in-depth weather forecast (three days comparative to five).

The other main competitor in the ring of weather APIs is that of Forecast by Wettercom. Forecast offers many of features that WeatherAPI has but expands on it in a few areas. One of the main areas that Forecast beats its competitor is with its actual forecasts, compared to an available three day weather forecast under the free plan of WeatherAPI, Forecast offers a fourteen day forecast under its free plan. Despite this, the major downfall of Forecast involves its limited number of requests that a user can make under its free plan and that it does not offer weather alerts.

At only ten requests allotted a day (300 a month), it ends up being a drop in the pool comparative to how many is allowed by WeatherAPI.

While both options have clear advantages over their competitors, we have decided to go with WeatherAPI due to the alert system that it provides and the vast number of requests it allows under its free plan. In order to expand on the additional comparisons that led us to go with WeatherAPI, the below table will delve into more detail.

Table 14: Comparison of WeatherAPI and Forecast

	WeatherAPI	Forecast
Calls Per Month	1,000,000 (No bulk calls at once)	300 (10 per day)
Forecast Days	3 days	14 days
Forecast Interval	Daily and hourly	Daily
Marine Weather Interval	Daily	N/A
Weather Alerts	Yes	N/A
Coordinate Based Data	Yes	Yes (Daily)

3.2 Part Comparison and Selection

3.2.1 Microcontroller

When figuring out what microcontroller we wanted to use as the brain of our project there were many different factors that we had to consider to ensure that we were choosing the best option for what we needed. It is because of it acting as the center-point of the system's operation and how much influence it will have on the performance of the system that this quickly became one of the first components we had to research. The microcontroller will be in charge of communicating with three sensors, outputting information to a display and speaker system, communicating with an external weather API, and using all this information to determine whether it needs to activate/deactivate the system. It is important to us for the system to not only do this quickly but to also do everything very efficiently due to this being an outdoor product that is meant to operate through severe weather conditions. It is with all these points considered, when looking into the best microcontroller for our project we felt the most important aspects to consider were communication protocols, I/O, memory, power consumption, any other modules that may exist on the MCU package, and availability. In order to properly delve into each of these factors, the below paragraphs will each go over an individual factor and discuss what we are looking for from it.

Considering that our microcontroller will be in charge of communicating with three different sensors, an external display, a speaker system, and a few other components it is obvious why having the right communication protocols on the chip is an important factor to making the correct decision. The three main serial communication protocols implemented in modern embedded systems are UART, SPI, and I2C. Each of these protocols come with their own advantages and disadvantages when it comes to implementation and later deployment. Despite this, it is important for our system to be able to communicate with the different sensors and components within the system and because of this we are looking for a chip that has multiple buses of each communication protocol. We decided on this because as we home in on the different sensors and components that we will be using in the system it is important to have a chip that is flexible enough that no matter what we choose it will still be able to communicate with it.

In a similar thought process of needing a wide variety of communication protocols for talking to the various sensors and components within the system, we will also be needing a chip that has enough I/O (GPIO pins) to support the various devices we will want connected to the system. At minimum we will have two motors that will require connection to a GPIO pin in order to control the activations/deactivations for the shuttering system. It is because of this that, despite not having as much importance comparative to other factors, having more than enough I/O is the approach we decided on in case other components are added in the future that will require being hooked up to one of the chips I/O pins.

In order to successfully flash the application onto the microcontroller and store it there for operation, having enough memory becomes the next critical step in qualifying a chip as the best option for our project. Taking this into account and recognizing that we will not only need enough memory for storing the flash and operating the program, but also any variable storage that may occur, it is critical to the operation of our system that we have more than enough ROM and RAM. In most embedded systems, having at least 256KB of ROM and 64KB or RAM tends to be a good rule of thumb to follow.

Because our system will be operating in severe weather conditions that makes having a source of power unreliable, it is incredibly important that we choose a chip that is capable of at least supplying the amount needed by any devices connected directly off of it without having a substantial amount of power left-over.

In addition to needing a chip that both performs as well as we need it to and has all of the specifications that we require, it is also important to consider what modules may be added onto the MCU package outside of just the chip. Many microcontrollers today have multiple skews of itself within its family which allow for a degree of customizability for the end-user to get exactly what they want. In this case we are looking for any additions to the microcontroller package outside of the integrated chip that would benefit our implementation of our application.

The last major factor that must be considered when searching for the microcontroller that will best suit our system, is ensuring that it has consistent and reliable source of inventory. The supply of the chip will impact everything from its cost to how long we will have to wait for it to arrive after ordering it. It is because of this that we will narrow our choices down to only those that have a substantial amount of their product in stock.

The below table compares multiple microcontroller parts that met most if not all of our qualifications and how they do so. In addition, it will identify the component that we will be using in our system.

Table 17: Comparison of Acceptable Microcontroller Options

Microcontroller	ESP32-WROOM-32E-N4	ESP32-WROOM-32E-N8	STM32WB35CCU6A	nRF52840-QFAA-F-R7
Communication Protocols	3 UART 2 I2C 4 SPI	3 UART 2 I2C 4 SPI	1 UART 2 I2C 2 SPI	2 UART 2 I2C 4 SPI??
GPIO	34 GPIOs	34 GPIOs	71 GPIOs	48 GPIOs
Memory	4MB Flash 448KB ROM 520KB SRAM 16KB SRAM in RTC	8MB Flash 448KB ROM 520KB SRAM 16KB SRAM in RTC	256KB Flash 256KB SRAM	1MB Flash 256KB SRAM
Power Consumption	3V~3.6V operating voltage 5μA hibernation mode 240mA during WiFi or Bluetooth transmission	3V~3.6V operating voltage $5\mu A$ hibernation mode $240mA$ during WiFi or Bluetooth transmission	1.71V~3.6V operating voltage 803mW	1.7V~5.5V operating voltage $16.5mA$ at radio transmitting $3.16\mu A$ with system operating
Availability	18000+ on Mouser	15000+ on Mouser	3000+ on Mouser	4000+ on Mouser
Additional Modules	Built in WiFi, Bluetooth modules, and PCB antenna	Built in WiFi, Bluetooth modules, and PCB antenna	Built in Bluetooth module	Built in RF module

3.2.2 Anemometer

Cup Anemometer:

A cup style anemometer was chosen as the sensor that will be used to measure the wind speed. A comparison of available sensors is shown in the table below.

Table 18: Comparison of Available Cup Anemometers					
Model	SEN0483	SEN0170	1733	TV-4-A	YGC-FS-24V
Communication Protocol	RS-485 Modbus Protocol	Analog [0-5V]	Analog [0.4-2V]	Analog/pulsed DC/AC	Analog[0-5V]
Operating Voltage	7-24V	12-24V	7-24V	10-36V	5V
Power Draw	Not specified	0.3W or less	Not specified	~25mW	Not specified
Range	0.4-32.4m/s	0.4-30m/s	0.2-70m/s	0.27-60m/s	0.5-45m/s
accuracy	(+/-)0.3m/s	(+/-)3%	(+/-)1m/s	(+/-)0.89m/s	(+/-)0.5m/s
Ip rating	N/A	IP65	N/A	N/A	N/A
Cost($)	45	48	44.95	769	66.9
Supplier	Digikey.com	Dfrobot.com	arrow.com	scientificsales.com	Amazon.com
Manufacturer	Dfrobot	Dfrobot	adafruit industries	Texas Electronics	Calt

Sen0170 manufactured by Dfrobot was chosen because it provides a compromise between cost effectiveness and features needed in this project.

Figure 02: Sen0170 Source: Dfrobot.com

The Sen0170 is constructed of aluminum alloy making it more rigid than other plastic designs. The Sen0170 also comes rated IP65 meaning the sensor can withstand extremely dusty environments as well as resistant to water jets in any direction. No other anemometers provided an IP rating. The price of the anemometer is $48.00 when sourced directly from Dfrobot's website. All comparably priced anemometers were plastic construction without an IP rating. Another feature of the Sen0170 is the analog output. The esp-32 microcontroller comes equipped with a built in analog to digital converter with a which will allow the esp-32 real time wind measurements. The wind speed sensor only measures the windspeed up to approximately 67mph but according to the national weather service sustained wind speeds can be hazardous as low as 40 mph sustained winds or gusts as low as 58mph. [S14] [S15]

3.2.3 Battery

LiFePo4 Battery:

I chose to target the 18650 form factor the battery because it is a small lightweight form factor and is very common with lithium battery chemistry. Additionally, I already own a charger for the 18650 form factor which will reduce the Bill of Materials cost.

Table 19: Battery Component Selection			
Model	PCIFR18650-1500	PSL-FP-IFR18650PC	PSL-FP-IFR18650EC
Nominal Voltage(V)	3.2	3.2	3.2
Capacity(mAh)	1500	1100	1500
Charge Voltage(V)	3.65	3.65	3.65
Charging Current(mA)	300	~	~
Max Charge Current(mA)	750	1100	1500
Max Discharge Current(mA)	4500	33000	4500
Cut off Voltage(V)	2	2.5	2.5
Cycles	2000	2000	2000

Price	5.26	7.18	5.07
Supplier	Digikey	Digikey	Digikey
Manufacturer	Zeus Battery Products	Power Sonic Corp.	Power Sonic Corp.

Unfortunately, there aren't as many LiFePo4 battery manufacturers as there are Li-Ion in the 18650 form factor. It is important however that LiFePo4 batteries are used since they are less volatile than regular Li-Ion. The PCIFR18650-1500 was selected for several reasons. The PCIFR18650-1500 offers great performance at a low cost with a max current of 4.5A and a low cutoff voltage of 2V. The PCIFR18650-1500 also is low cost at only $5.26 per unit. The PSL-FP-IFR18650PC was not selected because according to the manufacturer that battery is a "power cell" meaning it is designed to provide a high discharge current for short periods of time (up to 33A). The greatest power draw in our system should be the motor which is rated to draw 160mA at 6V which is 0.96W which is not a large load. The PSL-FP-IFR18650EC is a viable option at a lesser cost but the lead time for delivery is January '24.

3.2.4 3.3V Switching Voltage Regulator

The voltages needed in the project are 3.3V, 5V, possibly 6V for the DC motor, and 12-24V for the anemometer. The battery LiFePo4 battery chosen has a charge cut-off voltage of 3.6V and a discharge cut-off voltage of 2V. If we run 4 batteries in series, we will have a working range of 14.4-8V. When the batteries are fully charged, we will need two buck converters to step down the supply voltage. When the batteries are discharged to less than 12V we will need a boost converter to step up the supply voltage for the anemometer. All switching regulators were chosen using Texas Instruments WEBENCH. [S16]

3.3V Buck Converter:

The humidity, pressure, and temperature sensor IC BME280 and the ESP32-WROOM-32E are supplied with 3.3V. The BME280 only requires 3.6A at 1Hz and the ESP32 gives a minimum current of 500mA meaning the buck converter should supply at least 500.0036mA

Table 20: 3.3V Regulator Comparison					
IC	TPSM863252	TPS564252	TPS564257	LMR51610	TPS563257
Efficiency (%)	90.3	92.6	91.9	86.8	83.5
BOM Cost($)	1.09	1.05	1.05	0.85	1.05
BOM Count	10	13	13	9	13

Footprint (mm^2)	73	81	81	188	70

The TPSM863252 was chosen because it provides a compromise between a high efficiency, low BOM, small footprint solution. The TPSM863252 IC is flat with no leads and does not require an external inductor contributing to its small footprint and low part count.

3.2.5 5V Switching Voltage Regulator

5V Buck Converter:

The H-Bridge motor driver will be powered with 5V and have a maximum current draw of 2A.

Table 21: 5V Regulator Comparison				
IC	TPS564257	TPSM863252	TPSM863257	TPS564242
Efficiency (%)	95.5	91.6	91.5	93.5
BOM Cost($)	0.93	1.09	1.09	0.96
BOM Count	13	10	10	13
Footprint (mm^2)	173	79	79	125

Much like the 3.3V regulator the TPSM863252 offers a good combination of price, efficiency, and small footprint. Much like the 3.3V regulator this 5V regulator has an integrated inductor making the footprint small and reducing the BOM count.

3.2.6 12V Switching Voltage Regulator

12V Switching converter:

The anemometer is supplied with a 12-24V input, and the batteries have a working range of 8-14.4V. When the batteries discharge below 12V it would not be acceptable to lose the ability to sense the windspeed. When the supply voltage drops below 12V we will have to step the voltage up. A comparison of a few voltage boosting topologies are shown below.

Table 22: 12V Regulator Comparison				
IC	LM5022	LM5022-Q1	TPS55165-Q1	TPS55289
Efficiency (%)	60.1	59.2	54.1	80.4

BOM Cost($)	2.66	2.66	2.88	4.88
BOM Count	21	21	11	16
Footprint (mm^2)	210	220	317	208
topology	SEPIC	SEPIC	BUCK-BOOST	BUCK-BOOST

The TPS55289 is the most expensive and the most efficient topology found for a 12V solution. There was a lack of available parts for this regulator compared to the 3.3V and 5V step down regulators. The efficiency also took a hit but that is typically expected when boosting voltage.

3.2.7 Barometer, Humidity, and Temperature sensors

There are a few options to choose from when deciding on what barometric pressure sensor will fit our application and deliver the necessary data. Out of the many there are 2 candidates that were chosen for various aspects that they stood out in. Some of the things that were taken into consideration when choosing the right sensor were:

• Sensor footprint (size)

• Current draw

• Ease of implementation

• Cost

•Availability

• Range of sensing.

The first option that was investigated further was the MPL115A1. This sensor uses a MEMS pressure sensor that utilizes a conditioning IC to provide accurate measurements from 50 to 115 kilopascal (kPa) with an accuracy of ±1kPa (within the temperature range of -20ºC to 85ºC). This sensor features its own ROM to store calibrated data that is calibrated from the factory. The sensor also communicates via SPI protocol through a dedicated SPI port. Integrated ADC digitizes pressure and temperature readings that are then output through the SPI port. The build of the sensor also makes it desirable due to its small form factor, low power consumption, and wide operating temperature range. In sizing this sensor only takes up a 3mm x 5mm footprint on the board which allows for easy placement and overall smaller size of the sensor module that will be designed and placed in an outside location. Low power consumption also makes this sensor desirable as it will need to run on battery power should the power go out, which is a common occurrence during a hurricane, or any sever weather condition. In active mode it will only draw 5µA and will have the ability to be placed in a sleep mode that will only draw 1µA this will allow for optimization of battery life. Operation temperature also makes this a good choice as it will in a module that will be exposed to the elements. Outside temperatures and very wildly from day to day. The unit must also be able to withstand weather conditions throughout the year so that it only needs to be installed once and not every season. This sensor can handle a wide operating temperature range of -40°C to +105°C to fit demanding environmental requirements. This sensor also features a temperature sensor that is integrated within. The temperature sensor has a range of -40°C to +105°C.

After some further research a second option was found and selected over the first. The BME280 sensor has similar features to the MPL115A1 with improvements and more capabilities. Just like the previous choice the BME280 can in the same applications. It features a barometer with a range of 300-1100hPa (equivalent to 30-110kPa) with ±1hPa accuracy. This is roughly the same but with a lower low end starting point and 10x times more accurate. It can also read outside of the given range but with slightly lower accuracy. This sensor also features SPI communication but can also use I²C. In terms of size and efficiency this sensor also outperforms the MPL115A1. Coming in at only 2.5mm x 2.5mm this sensor is about half the size. As far as efficiency this sensor is also more efficient by a considerable amount. Using all 3 integrated sensors it only consumes 3.6 µA in normal mode. In sleep mode it consumes .1µA which is 10% of the MPL115A1 sleep mode current consumption. This will significantly improve battery life in comparison. The BME280 also features a temperature sensor and a humidity sensor and is $1.52 lower in cost. The Temperature sensor has a shorter range of -40°C to +85°C which is still more than enough needed. The humidity sensor gives results in percentage from 0 to 100% humidity. The only downside to this sensor over the other is the slightly shorter range. However, in this application it does not affect the overall performance of the system.

Table 23: Comparison of Barometer Options

Barometer	MPL115A1	BME280
Power supply	2.375 V to 5.5 V	1.71 V to 3.6 V
Digital interfaces	SPI Interface	I2C (up to 3.4MHz), SPI (up to 10 MHz)
Atmospheric pressure range	50 kPa to 115 kPa	300-1100 hPa
Temperature range	-40°C to +105°C	-40°C to +85°C
Humidity range		0 to 100%
Current consumption	5µA active mode 1µA sleep mode	1.8 µA @ 1 Hz humidity and temperature 2.8 µA @ 1 Hz pressure and temperature 3.6 µA @ 1 Hz humidity, pressure and temperature 0.1 µA in sleep mode

Size	3mm x 5mm x 1.25mm	2.5mm x 2.5mm x 0.93mm
# of Pins	8	8
Cost in Dollars	$7.95	$6.43
Additional features	Monotonic Pressure and Temperature Data Outputs	Also measures humidity and Temperature.

4. Standards and Design Constraints

Throughout this section we will delve into the various standards and design constraints that are necessary in order to successfully create the automatic shuttering system. These will play an important role in the process of creating the automatic shuttering system and ensuring that it operates as expected while still considering the design constraints that come with developing this type of product.

4.1 Related Standards

During the development process for an engineering project there are many rules and requirements that must be considered in order to create a successful product that meets the needs required by the industry and its customers. For the development of our project, The Automatic Shuttering System, we will be creating a custom PCB that contains connections to multiple different components of our system. Additionally, the PCB will host a MCU package that will communicate with / operate these components in order gain useful data to help in its decision making for operating the shuttering system. It is because of this complexity, with the multiple different aspects of the design process, that these standards are so important. The standards below will layout a clear path for the development of our project so that we can ensure the creation of a reliable product.

The following subsections will delve into the various standards that are relevant to our project with their name and its upholder. Each subsection will give a brief summary of the standard and how it relates to our project. As the project develops and new components are found we may end up updating the below subsections to better reflect the standards that are relevant to our project.

4.1.1 Electrical and PCB Standards

ICP-2221A Generic Standard on Printed Board Design

This standard presents the generic requirements that are needed when designing a PCB and was created by the Institute For Interconnecting and Packaging Electronics (IPC). This standard defines almost everything that could be thought of when designing a PCB and greatly affects the choices that are made when designing it. As we develop the PCB for our automatic shuttering system, we will have to keep this standard at the forefront of our minds in order to ensure that we create a safe and reliable PCB. The standard will influence the materials we use, the spacing between all the components, the size of the traces, and much more. When laying out / designing a PCB one of the most important aspects to keep in mind is how to run your traces and how large they should be. This standard delves into the proper way to lay out your traces and how to properly calculate the proper width / length of a conductor. When it comes to laying out your traces on the PCB, the rule this standard provides is to maximize / optimize the spacing between your conductors (traces) while also minimizing the length of the conductor between two lands. Furthermore, when laying out your traces to calculate the width of the trace based on supply current you use the formula $W = \frac{A^2}{Thickness * 1.378}$ and to calculate the area of the trace you use $A = \frac{\max current}{layer\ constant * temp^{1/.0725}}$. To expand on some of the other design requirements, listed in the table below are some of the key requirements that must be kept in mind when laying out / designing the PCB for this project.

Table 24: PCB Basic Layout Requirements	
Feature	Clearance
Component Leads	.13mm (up to voltage of 50V)
Test Probe Sites	80% component height (min: .6mm max: 5mm)
Mounting Hardware	<6.5mm below PCB surface

IPC J-STD-001 Standard Soldering Requirements

This standard delves into the specifications and requirements that are necessary to create high-quality soldered interconnections. This standard is upheld by the Institute For Interconnecting and Packaging Electronics (IPC) and elaborates on the materials / equipment used, mounting of components and soldering them, cleanliness after operation, and much more. For the purpose of this project, this standard will guide us when connecting the multiple sensors to communicate on the same wires and mounting the components to our PCB. Additionally, this standard will greatly influence the materials that we use for our solder and the accuracy of our solder to ensure that we are leaving very little residue. To expand on what this standard entails, in the below table is a general overview for the materials that are permitted and the general procedures that are to be followed.

Table 25: General Soldering Requirements	
Permitted Solder Alloys	Sn60Pb40, Sn62Pb36Ag2, Sn63Pb37, or Sn96.3Ag3.7
Permitted Flux	Rosin and Resin (with activity levels or L0 or L1)
Lead and Wire End	Should not extend over the terminal by over one lead diameter

Universal Serial Bus (USB)

This standard delves into the specifications and requirements for connecting, transferring data, and powering through the use of a universal serial bus connector. There have been many organizations over the years that have dealt with the upholding and development of the universal serial bus standard but in recent years the upholders have been the USB Implementers Forum (USB-IF). In today's day and age, USB is the de facto choice in the majority of computer-to-device communication, whether that be in their ever popular USB-C variation or older interfaces such as

USB-B. For the use of this project, we will be utilizing the universal serial bus standard in order to flash our ESP32-WROOM-32E-N4 with the application for running the automatic shuttering system. In order to successfully flash this microcontroller, we will be utilizing an USB-to-UART convertor to send the data of the application from a computer over to our microcontroller.

IEC 62133 – Safety Testing for Lithium Ion Batteries

This standard is currently being upheld by the International Electrotechnical Commission and delves into the requirements and tests that must be performed to ensure the safe operation of portable sealed lithium cells/batteries. Utilizing this standard in the design and deployment of a product ensures that the batteries will be safe during operation and reliable for a broad genre of applications. For our project we will be using this standard as a benchmark to guarantee that our implementation of LiFePo4 batteries within our system will be completely safe when finished and reduce the risks of any accidents occurring.

4.1.2 Wireless Communication Standards

IEEE–802.11b/g/n

This standard was issued by the Institute of Electrical and Electronics Engineering (IEEE) and acts as a guideline for wireless communication. The different categories to this standard are differentiated by the maximum transfer speed and frequency that a network can achieve. For the development of the automatic shuttering system, we will be using this standard in order to connect to the internet wirelessly for access to a local weather API and any external communications that are needed. For this project we will be utilizing what is commonly known as WiFi 4 which supports transfer speeds up to 150 Mb/s and frequencies of both 2.4 GHz and 5 GHz. The esp32 package that we will be utilizing as the center-point of our application is equipped with a WiFi module that is able to hit transfer speeds up to 150 Mb/s and a frequency that operates between 2.412GHz and 2.484 GHz. Additionally, because of the way that this standard is maintained it requires backwards compatibility with the previous iterations of the standard, this will greatly improve the longevity of the product because it will allow the system to still be fully functional no matter what new wireless standards are released in the future. To expand on the capabilities of the previous iterations of the standard, the below table will convey the specifications for some of the iterations that our microcontroller is compatible with due to the standard's backwards compatibility.

Table 26: Compatible IEEE Wireless Standards

	Frequency	Data Rate	Range
802.11b	2.4 GHz	Up to 11 Mb/s	35-100 meters
802.11g	2.4 GHz	Up to 54 Mb/s	38-140 meters
802.11n	2.4 GHz 5.0 GHz	Up to 600 Mb/s	70-250 meters

802.11ac	5 GHz	Up to 6.9 Mb/s	35-100 meters
802.11ax	2.4 GHz 5 GHz	Up to 10 Mb/s	70-250 meters

ECMA-404 The JSON Data Interchange Standard

This standard defines the proper syntax that all JSON text must adhere to in order to be considered the correct format. JSON allows for an interconnect between text that is both human readable/writable and text that is easy for computers to parse/generate. It is because of this ease-of-use that for many APIs it is the de facto format that is used when sending out its data to anyone accessing it. For the automatic shuttering system when reading from the weather API we will be needing to properly parse the data that we receive in order to gather meaningful data from it to help with the decision making when it comes to activating / deactivation the shuttering system. It is because of this importance that we are using JSON to read the data because it will be simple to parse in our application.

MQTT Version 5.0 OASIS Standard

This standard defines the process of utilizing the mosquitto messaging protocol for machine-to-machine communication over the internet. Throughout the standard it delves into the technical specifications and formatting that is needed for a successful network to exist. The messaging protocol (mosquitto) that this standard is based on utilizes a broker that acts as a communicator / distributer of information between publishers and subscribers and this standard defines rules and guidelines for how to properly implement it.

The Version 5.0 OASIS Standard, compared to that of earlier iterations, addresses the limitations of its predecessors by:

- Expanding on debugging tools (through reasons code, will properties, etc.) .
- Improving performance and reliability when handling messages.
- Defining new fields in the packet to improve message handling.
- Adding features not available in previous standards.

For this project we will be using Version 5.0 due to the vast improvements that it a has compared to the standards before it and its acceptance in the ESP32 family. For the automatic shuttering system, in order to reach our advanced goal of creating a website / database that stores the data from the system and being able to perform remote activations / deactivations via the website we will be utilizing MQTT publishing / subscribing communication feature with the Version 5.0 OASIS Standard to ensure that we are properly formatting and including everything necessary so that we can have a fully functional and fleshed out system. In our system, using MQTT we will have our three sensors act as our publishers in the network and the server / website acting as our subscribers / publishers. Furthermore, to orchestrate the transferring of these messages to and from the subscribers / publishers we will have our MCU act as a broker to handle getting the messages to the necessary parties. To expand on the functionality of MQTT, the below figure gives a simple portrayal of how the protocol the standard is based off of works.

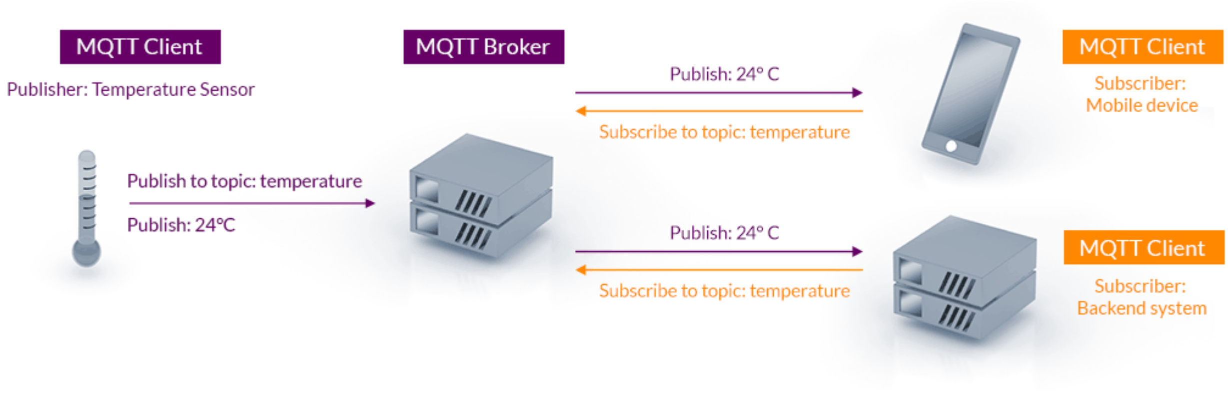


Figure 03 - MQTT Networking Representation

Bluetooth Core Specification 4.2

This standard defines the technical specifications for the Bluetooth protocol and all of the features that it has in this version. The various iterations of the Bluetooth standard vary in its features, transfer speeds, power consumption, etc. Contained within the MCU package for this project is a Bluetooth and Bluetooth LE(low energy) module that is certified to be compliant with Bluetooth Core Specification 4.2. Version 4.2 comes with a host of features that will be incredibly useful for any wireless communication that we may implement between our devices. Expanding on version 4.2, some of the important features this version brings to our project are dual-mode operation (low power (LE) and enhanced data rate (EDR)), transfer speeds of 1Mb/s (LE) and 25Mb/s (EDR), and a range of 60 meters (600 ft). The Bluetooth protocol that this standard is based on works by using high frequency radio waves to exchange data between different devices. This approach leads to many advantages, compatible with many different types of devices, however due to it using high frequency radio waves Bluetooth is incredibly susceptible to issues over distance.

These features will be incredibly useful in the implementation of our automatic shuttering system because it will be important to have this system be as power-efficient as possible while still having systems in place that allow it to communicate with other devices when WiFi networks go down. In addition to the Bluetooth module on the esp32 package being Bluetooth 4.2 certified, the module also contains a class 1/2/3 transmitter, AFH, CVSD, and SBC. To expand on the different classes of transmitters, listed in the tables below are the different classes for Bluetooth transmitters with their specifications.

Table 27: Bluetooth Transmitter Classes		
Class	Maximum Power	Operating Range
Class 1	100 mW (20dBm)	100 meters

Class 2	2.5 mW (4 dBm)	10 meters
Class 3	1 mW (0 dBm)	1 meter

4.1.3 Software Standards

ISO/IEC 9899:2011 – Programming Languages – C

This standard defines the way that programs are written and compiled when using the C programming language. For the development of our project, because we are using an embedded system, we are going to write and compile the code using C in order to keep our application efficient, have hands-on access to the hardware, and keep a light footprint. We will be version C11 due to its updates on previous versions while still maintaining the lightweight and reliable foundation that the language is known for.

ISO/IEC 30141:2018 – Internet of Things (IoT) – Reference Architecture

This standard provides a standardized approach to developing the architecture of an IoT device and is being upheld by the International Organization for Standardization and the International Electrotechnical Commission. It delves into laying out common vocabulary, designs, and industry best practices that are to be used to create a system that focuses on proper communication, privacy, and many other fundamental aspects to the development of an IoT device. In order to successfully complete our advanced goal of sending the data from the system to an off-site server to be displayed on a website we will be utilizing this standard to guide us in creating a fully functional and efficient IoT system.

4.1.4 Construction Standards

IEC 60529 – Ingress Protection Standard

This standard is upheld by the International Electrotechnical Commission and uses the Ingress Protection rating system to rate the amount of protection that an enclosure for an electrical

Figure 04 - Ingress Protection Rating Guide

system gives for the components inside of it. The Ingress Protection rating system that this standard utilizes was created to grade the resistance that an enclosure has against the intrusion of dust or liquids. To expand on the many classifications and categories that this standard references, please see the below figure. For the purposes of this project, we will be using this standard to guide us in the creation of our housing unit to ensure that the way we design the enclosures and frame are built in a way that make the system resistant to outside forces in order to fully protect the components.

4.2 Realistic Design Constraints

When beginning the process of starting a new project or creating a new product, some of the most important factors to figure out are what design constraints will affect the development process. For the development of an automatic shuttering system there are many design constraints that must be considered from ones we've imposed onto the project (such as making the system as cost-effective as possible) to ones imposed by outside forces (such as having to develop and deploy the project in a fix amount of time). No matter the scale of the constraint, each design constraint will affect the development of our project in some shape or form.

The following subsections will delve into the various design constraints that will affect the development of our project. Each subsection will give a brief summary of what the design constrain is followed up by how we plan on addressing said constraint. As the project is developed and a clearer picture of implementation is created, it is possible new constraints may be found or new approaches to overcome pre-existing constraints are discovered. In these situations, the below subsections will be updated accordingly.

4.2.1 Economic and Time Constraints

As we began laying out the blueprint for how we wanted to develop an automatic shuttering system, one of the first decisions that we made was that we wanted to make the system cost-effective without sacrificing on features and longevity. This constraint alone greatly shaped the trajectory of our project and any decisions we would subsequently make. Expanding on this constraint, one of the major reasons that we want the system to be cost-effective is because we feel that the areas and people that need this system the most shouldn't have to put their financials in jeopardy to feel safe during uncontrollable weather events. Furthermore, because this project is self-funded there is only so much that we can pull together for financing this project. In order to address this economic constraint, we have put a heavy emphasis on research to ensure that we are getting components that both meet our standards / requirements and do not come with a hefty price tag.

Beyond the economic constraints that have been imposed onto this project there also exists an issue of time. Having unlimited time for both the development and deployment process of a project/product is a luxury that very few are lucky to have. For the development/research phase of this project we are allotted roughly 12 weeks to find a group, determine a project, perform research on how to complete said project, and write a paper discussing said research. From here, the project will then enter the deployment phase where we will take all the research we've collected and begin applying our gathered knowledge to create the project. For this stage of the project, we will be allotted roughly 16 weeks before we have to submit everything for final evaluation. It is because of this that we need to put a heavy focus on our time management to ensure the project stays progressing. In addition, another time constraint that is imposed onto this project is that all the group members have extracurricular activities (mainly work/internships and other projects). In order to successfully address these time constraints, we have setup milestones throughout the next two semesters to ensure that we are not only staying on track but are ahead in case any unplanned issues arise. For example, one policy that we are implementing for all of the deadlines we come across over the 30 week timeline is to have all work completed at least five days beforehand to leave room for any formatting to occur or for us to address any last minute issues that arise.

4.2.2 Environmental, Social, and Political Constraints

When the project is fully completed and operational, the automatic shuttering system will consist of multiple sensors and many different electrical components that each have their own set of impacts on the environment and power requirements. With the system being a fully outdoor product, one of the first environmental constraints we will run into is power. With the automatic shuttering system meant to be able to run in almost any weather condition it is critical to the development process to ensure that our system is being efficient with the energy it has received and is not reliant on large amounts of power to operate. It is because of this that we put a heavy focus on using low-power components that do not leave an environmental impact (through waste or harmful materials). Additionally, in order to make sure we are being environmentally conscientious we are going to be using lithium iron phosphate rechargeable batteries (LiFePo4). We specifically went with this choice for the batteries because they are widely considered to be one of the greenest forms of batteries on the market.

In addition to the environmental constraints that are imposed on the project, we will also be dealing with political constraints that come with it as well. When it comes to setting up this system in a real-world situation, we will have to put research into the different political regulations that exist for the markets we would want to push our product out into. Each region/country may have different guidelines and regulations that an outdoor IoT device will have to comply with to be operational in these areas. For example, to achieve our advanced goal of sending data from the system to a remote server (for website purposes) we will have to make sure that we properly follow the guidelines for how to handle user-data properly and that we are not collecting/sharing the data in illegal ways. It is because of regulations like this, that one of the political constraints that will affect this project are the laws and regulations present in the areas we would want to deploy the project. In order to address these regulations properly we will have to put time into looking into the areas we would want to deploy and ensure that we are meeting the requirements and expectations for the laws of that area.

The areas that are affected by severe weather conditions around the globe play host to many different people and cultures. It is because of this that when designing our project, it is important to design our system in a way that makes it accessible / inclusive for customers of different abilities and setup in a way that does not alienate people of different backgrounds from being able to interact with / control the system. Additionally, with the many different areas that are affected by severe weather conditions every year it is important to design out system to be easily deployable on the many different architectures that exist around the world. To expand on both these points, we can ensure our project is accessible to all users by making the interface easily readable (using symbols and numbers), implementing a speaker system for those with hearing difficulties, and making the system easily moveable.

4.2.3 Ethical, Health, and Safety Constraints

Before the project can be fully developed on the hardware and software side of things, we first have to lay out a few ground rules to address the ethical, health, and safety constraints that come with building this type of system. When looking at the ethical constraints that will affect this project, one of the most common that affect the majority of IoT devices in the market is that of privacy and data security. Living through the age of information it comes as no surprise that the constraints of privacy and data security are at the forefront of IoT discussion and design. Despite information acting as the main product in many of today's markets/industries, we fully intend to leave our project out of it and maintain a secure system that focuses on user privacy and keeping their information secure. Expanding on this we will utilize, secure communication protocols and standards to ensure our users information stays secure and does not fall into anyone else's hands. In addition to making sure the data is transferred securely, we will also be only collecting the minimum amount of data that we need (from the sensors, status of the system, etc.) for the system to be fully operational. These steps will ensure that our user's information is being taken care of in a respectful way.

Beyond the ethical constraints that come with building an IoT device, we also have to focus on the health and safety constraints that will come with building an automatic shuttering system. The main health/safety concerns that will come with building this project is ensuring that the housing system is able to be operational without adding any risks to the users and area around it. Elaborating on this, the housing unit will contain many moving parts that could potentially cause physical harm if not implemented properly. It is because of this that we will be implementing safety mechanisms into the product to ensure that does not cause physical harm to any person. One example of a safety mechanism we plan on implementing is utilizing the speaker system to notify nearby users when components will begin moving so that they can get out of the way.

4.2.4 Manufacturability and Sustainability Constraints

When designing a project that is meant to be able to survive/withstand severe weather events there are inherently many logistical factors that must be considered. For the development of our automated hurricane shuttering system, it goes without saying that this product is intended to be operational in weather conditions from mild rains to severe hurricanes. It is because of this intended operation that we have the manufacturability constraints of making a product that is able to survive in almost any weather condition while also being adjustable enough to fit onto most windows. For the construction of the project, we are planning a modular setup for the housing unit. This will consist of two separate enclosures that are joined together via a frame that is placed around the perimeter of the designated window. One of the enclosures will contain the three sensors we will be using in the system and the other will contain the MCU, LCD display, and speaker system. It should be noted that one of the sensors, the anemometer, will be station on top of the enclosure with a cable being run securely to inside the enclosure. Additionally, the anemometer is IP65 rated and built to handle these types of scenarios which makes it a perfect choice for our system. From here we will have the motor for the housing unit deployed into the wall to make sure that it can stay secure during any situation. In order to address the survivability for the enclosures and frame we will be making them out of a sturdy plastic that is resistant to changes in heat and other environmental factors. A popular option that we have been looking into is ASA 3D printing filament due to its study and resistant nature.

Despite the clear requirement for needing our system to be built with sturdy materials and deployed to survive, it is also incredibly important to consider how these choices will affect the environment that the system will be getting placed into. It is because of this that when looking into the materials we wanted to use and how we wanted to deploy the system we took a keen interest in making sure our choices were ones that wouldn't harm the environment but also promote longevity. Expanding on the choice of the plastic we mentioned earlier, another reason we chose ASA 3D printing filament for our enclosures and frame is due to its recyclability and how well it maintains its structural integrity in harsh weather conditions over an extended amount of time.

5. Comparison of ChatGPT with Similar Platforms

5.1 CHATGPT: Limitations

Every new and emerging technology like ChatGPT has its limitations whether it be environmental or power or even broad scale usefulness. At a broad level the first and most prevalent limitation of ChatGPT is its knowledge base. It is basically a giant library of cumulative knowledge of the internet. More specifically it is trained in software manuals, internet, and events plus a wide range of programming languages. This at first seems like a great thing to have under its belt as these are all common ideas that users could possibly have questions about. The big drawback is how it gets these datasets and how it is trained. The internet is a large place that isn't always a factually driven environment. This being said if ChatGPT is trained on opinion-based articles it could become misleading and harmful to society as a whole.

Furthermore, its training in programming languages is limited to what it can find publicly and the archaic programming texts from when the languages were first developed years ago. This is a major limitation as the information from when the languages are first created are correct, but it is very conceptual and most of its questions won't be people trying to learn the programming language for the first time. It probably will be real programmers that are trying to utilize ChatGPT to create a new piece of code that hasn't been seen before. This will be a notable point of failure if not a place where it will struggle and must ask a multitude of questions in response or give a generic not code output.

The next major place where Chat GPT can show its limitations is in software manuals. This is aimed at teaching people about different software packages from IOS to Microsoft windows all the way to Linux. This can be challenging as it might try to combine its software manual knowledge and internet knowledge and give some type of inaccurate half opinion-based answer and half highly technical software manual answer. This would leave most intermediate experienced people stunned and all new or beginner level people absolutely dumbfounded. Plus, if it leans to either side of those two previously mentioned parts of its database the answer could become too technical for a beginner or have too much slang and modern terms for beginners.

Overall ChatGPT has some serious limitations that should be addressed by having a human better train it on the datasets it has been provided by the internet. A basic solution that I have learned a lot about in my classes at UCF would be some type of confidence level indication system. This would include taking in information and questions and giving them a rating based on whether it solved the problem or not. Adding one to the confidence level indication system would indicate that the system did well and solved the problem. Conversely if the system didn't produce an answer that both an administrator and client didn't deem acceptable to be a solution to the problem then the confidence level indication system would lose a point indicating that it isn't the correct solution, and the answer should not be used again without modification. Another way to overcome the inaccuracy problem is to prescreen some of the more controversial opinionated sources and make sure they have some level of validity even if you personally disagree with what the piece is referring to. Lastly a system could be employed that lets users of ChatGPT mark solutions to questions or queries of a scale of one to ten on how well it solved their problem and if they would recommend it to another person with a similar question. While ChatGPT still has some hurdles to get over before it can replace other similar products like google it is well on its way to producing a competitive and all-encompassing product.

5.2 CHATGPT: Advantages

With the limitations of ChatGPT clearly laid out there are some distinct advantages of ChatGPT and its capabilities. These include but are not limited to quick basic knowledge of general day-to-day information like getting tips and tricks on how to do basic mathematics or some historic weather data or even remembering the planets order. It also has some basic technical skills when it comes to advanced topics like electrical engineering and problem solving. Lastly it has programming skills that exceed the basic level knowledge of a first-year computer science major. It also can quickly and easily convert from one programming language to another.

To further expand on its general day-to-day knowledge capabilities. ChatGPT has shown it is able to remind people not only what the quadratic equation is or the Pythagorean theorem, but it also gives some context on how to use these basic formulas. You could also reasonably expect it to give you historical data when it comes to weather. This could be somewhat useful in our project seeing that historic data on hurricanes or hurricane conditions and paths could be useful to determine the appropriate data to trigger our system with to properly detect a hurricane. Another major aspect of its daily knowledge could be something like recalling the orders of the planets and their names. This doesn't have any core relations to my project but does show some of the extents that ChatGPT has been trained to and its future possibilities.

Delving deeper into its technical skills and problem-solving abilities, it shows promising results for things like homework and the basic levels of problem solving that those types of problems bring, and all the way to circuit design in electrical skills. For instance, I tried to give it some basic questions on what a voltage divider circuit is and how it is used, and it gave not only accurate answers but was able to label a fake circuit it created in a terminal application with symbols and dashed lines for wires. It then was able to explain change the resistor ratio gave different desired voltage outputs. Another basic circuit design or component that it was able to explain or answer correctly was an operational amplifier. After reminding it that you wanted to operate in ideal conditions with infinite input resistance and zero output resistance and infinite gain possibilities it was able to give an even more accurate description of the component and how it works. It was then asked generally how it was used and it gave a generic answer about some of the most frequently used circuits, but it wasn't wrong by any stretch of the imagination. Then I gave it one of my basic calculus problems from calculus one and it was able to accurately derive the answer even if the format left a little to be desired.

Lastly its programming skills. They are one of the best parts of the whole AI system. ChatGPT was able to take one of my college level programming homework problems and accurately produce a working version of the answer on the first try. It was then also able to switch from one language to another and still have the program work as it was supposed to. I then tested it again with a more advanced problem from a friend's upper-level computer science class to my surprise it was able to gain reproduce a working piece of code that did exactly what it was supposed to. I then challenged it to do some extraneous things with the program and it did need to ask a couple follow up questions but, in the end, it gave a faithful answer that did solve my assortment of random extra tasks. Overall, this part of ChatGPT seems to be the most trained and was able to be highly adaptable to different programming related challenges. This is considered pretty good since it is getting information from chat forums like GitHub which isn't always reliable.

5.3 CHATGPT: Disadvantages

With every advantage comes a disadvantage. I am always reminded of this with the saying "every technology is true neutral it can be used for good or bad". Just as everything can be used for good or bad technologies come with advantages and disadvantages. Focusing on the main ones, we will look at its inability to explain high level concepts of engineering with multilevel variable and large circuit topologies. We will also look at ChatGPT's abilities to comb through data quickly as well as its data sets age and slightly outdated information. Lastly, looking at its true limits when it comes to programming and where it start to struggle. Even though the previously mentioned its programming skills are great everything has limits and I have explored ChatGPT's.

Starting with complex or high level multi variable problems. These situations are a large struggle and major disadvantage for ChatGPT. The best situation I can recall is the time I gave it a high-level electronics problem that aimed to test our knowledge of current sources and it wasn't able to create a circuit that accomplished the goal of producing a certain amount of current. This was mainly due to its inability to solve a multi-faceted problem like that that requires some design knowledge. Anything past one variable and one output seems to be too much for ChatGPT. I also gave it a problem about developing a solution to another design problem where the goal was to use a specific combination of resistors capacitors operational amplifiers and a transistor to create a voltage regulator and it got very confused and went in circle asking for the same information in different ways. This ultimately resulted in a incorrect answer even after following it down the rabbit hole of questions it tried to use to get the correct answer. Lastly, I gave it a design problem from the electronics lab, and it wasn't able to even develop a simple circuit to measure and output different voltages depending on the temperature of the room. This was a challenge due to ChatGPT not knowing the specific thermistor and the other resistance value. This was shocking since just assuming one resistor value would have solved the problem, but it kept going in circles to an eventual poor answer.

Next is ChatGPT's ability to comb through data and the usage of old data sets. The first obvious downside is its relatively outdated data set. I tried to ask it for UpToDate weather information, and it failed to do so because its latest information is from 2021 and said it didn't have access to current information. This is huge because competitors like Google and Bing already have integrated AI products that use up to date information that can give me such information. I also tried to ask it to make historic stock market predictions and it was unable to do so because it was dataset limited and didn't have all the historic data to make these types of predictions. Competitors in this space like yahoo and NASDAQ both had this data readily available to me.

Last is ChatGPT's upper limits when it comes to programming and programming related knowledge. In the previous section of advantages ChatGPT came out ahead in many cases but that wasn't the case every single time. There was an advanced matrix problem that I gave it from my time in college and it struggled very hard to faithfully reproduce a working piece of code. IT also struggle to create code that references large preset datasets from text files and writing to those text files. The last piece of code it struggled with was the ability to read existing code and modify it to meet new requirements and standards. It would attempt to rewrite the code from scratch then apply the new goals. Overall, this is still one of its best features.

5.4 CHATGPT: Case Study 1

The first major piece of information that I tried to extract from ChatGPT directly related to our project of the hurricane shutter and detection system was the speaker choice. Specifically what speaker would be ok for the applications and the different types of speakers are on the market in general. It both showed advantages and disadvantages when it came to picking the speaker.

The advantages included give accurate and basic knowledge of the three most common speaker types. These includes a midrange, tweeter, and subwoofer. It accurately describe the pros and cons of these three types. Thes included the midrange being a good all-around speaker, being able to produce accurate sounds from a decent range of audible sound and being a less costly option compared to the other two. It went on to explain the tweeters are used for high frequency applications and could be more costly due to their specialization of sound type and form factor. Finally, it was able to explain to me the main purpose for a subwoofer type speaker and that it was mainly used to reproduce low frequency sound and was a very costly part of most sound systems as well s it being a huge speaker that is typically a very hard part to fit into smalls spaces. So, it was able to give me things I could get from Googling basic or simple questions that I gave to ChatGPT. In this regard it didn't help a lot, but it did refresh my memory on specific ranges of the speakers and some of their individual cost, seeing as most speakers for home use come in package deals hiding their true cost. It was also able to led me on to the fact that I might need a amplification circuit. It didn't directly day this, but it kept including a need for a system that would interface with these types of speakers to control them and that power was a common issue.

Now the disadvantages, ChatGPT couldn't give me a specific product to use and couldn't give me some examples like YouTube videos or forum posts to look at to further in my decision-making process. Plus, it also couldn't get me specific microcontroller speakers that are typically used since it's not a super common application unless it's used to produce basics beeping sounds. Further on the inability to give me examples I had researched a little bit on speakers beforehand and used my previous knowledge seeing as I have installed a home sounds system before and it would have been very usefully to point me towards a YouTube video on sounds systems or speaker usages in microcontroller application. It also could have been useful to point me towards the microcontroller community that I specified and their forum where audio applications were listed as one of the topics of major discussion. More about the microcontroller specific information. It gave me the datasheet for the controller or where to find it but never gave me any specific examples of products that would work or have been seen before working. This is a double-edged sword in my opinion since it could become biased by large companies wanting to push their products but on the other hand some simple images of what to look for could have sufficed.

Overall, in the selection process ChatGPT was semi useful. I would give it a rating of 6/10. It still needs some improvement on giving proper suggestions even if it must stay at un unbiased high-level explanation. On the other hand, it was able to successfully narrow down the selection from extraneous answers quickly by giving me helpful information on speaker types. It also helped with understanding the interfacing and discovering the need for amplification or a further level of control and power.

5.5 CHATGPT: Case Study 2

The second major piece of information that I tried to extract from ChatGPT directly related to our project of the hurricane shutter and detection system was the amplification circuit choice. Specifically what amplifier would be good for the applications and the different types of amplifiers that are on the market in general. It both showed advantages and disadvantages when it came to picking the amplification circuit.

The advantages when it came to circuit design and selective of the amplification circuit were the ability to let the AI try and create on from scratch and further my skills of circuit design and understanding. First it was ChatGPT's ideas to use an amplification circuit so that is the first major contribution it made in the decision process. It then suggested some basic circuits that didn't work for my application but gave me an idea on how to approach the idea of finding the correct circuit for my specific setup. Next, I was able to better understand what I needed due to it recommended picking the type of amplifier circuit first based on the type of power I am going to be using. This was an obvious choice seeing that my system was using batteries and dc voltage regulator to give me the power required to amplify my circuit and produce enough power to drive the speaker previously selected. The next problem it led me through was the problem of the loading effect, it was only mentioned slightly at first, but I then asked it further. I confirmed its validity and knowledge of the loading effect from my own knowledge and was able to conclude it had valid concerns about the resistance value I was aiming to use. Next it furthered my skills by explaining the differences between the types of amplification circuits like AC vs DC amplification circuits and their common uses. After that it helped with discussing the main uses for each and how each has some nuances that can be better for specific applications.

The disadvantages of ChatGPT when selecting an amplification circuit were very apparent. These included but were not limited to the inability to accurately display circuits, the inability to modify those displayed circuits, and the inability to explain changes and their effects in both AC and DC applications. ChatGPT struggled to accurately display these circuits so I can visually see them instead of having an arbitrary image in my head. This was less apparent earlier as it was able to display basic circuits with a total of around five components but it back evident that after five components the design becomes convoluted and hard to grasp. On top of that the symbols became very hard to understand as it tried to formulate equations and used an overwhelming amount of sub symbols to try and explain what it was trying to create. Then asking it to modify the circuit ChatGPT completely ditched the circuit and redesigned components that I didn't specifically instruct it to change in what seems to be a weird attempt to simplify the circuit. After that I asked it what it did and why it did it and it was only able to give me what I would describe as a robotic empty answer that just reiterated high level concept instead of getting to the root of the change.

Overall, in the selection process ChatGPT was barely useful. It gets an overall score of 4.5/10. This is because of its inability to explain its thinking process specifically and to improve upon its design without completely changing the circuit. It does have some redeeming qualities like talking about not specifically the parts I describe because it led me to need more components than I originally though and it was able to explain concepts at a high level that could be useful.

5.6 CHATGPT: Case Study 3

The third major piece of information that I tried to extract from ChatGPT directly related to our project of the hurricane shutter and detection system was the sensor choice. Specifically what sensor would be good for the application and the different types of sensors that are on the market in general. It both showed advantages and disadvantages when it came to picking the sensors.

The major advantage of this was ChatGPT's ability to define what types of sensors could be useful for the hurricane shutter and detection system. Plus, which parameters should be explored to help determine if a hurricane is occurring or a lucky set of circumstances are occurring that are like that of a hurricane. This included recommendation for sensors that quantify temperature, barometric pressure, window speed, and humidity. It specifically helped when choosing a wind speed sensor because it helped me understand there are many different types of windspeed sensors, and they all have distinct advantages and disadvantages. The first one it discussed was a cup anemometer the second was a sonic anemometer the with was a weathervane and the last was a LIDAR solution. This got me to focus on two solutions the cup anemometer and the sonic anemometer. Thes both seemed promising since they would fit within the parameters of our microcontroller constraint and the pack size constraint. It also helped me find great options for the temperature sensor. These include thermocouples, resistance temperature detectors, thermistors and infrared. All of these seemed promising after reading their basic descriptions and their capabilities, but it ultimately led me to believe a thermistor or resistance temperature detector would be a good choice for our application and package size requirements. Lastly it helped pick out the humidity sensor. It gave options like a capacitive sensor, a resistive sensor, and a thermal conductivity humidity sensor. These again seemed like possible solutions until further research was done and that pointed me towards a resistive solution.

Again, ChatGPT isn't perfect and had many disadvantages when it came to picking sensors. It spammed my options for all the different sensors and left me to do a lot of individual research for which one exactly worked for my solution even after trying to convey that I needed it for a certain application. It yet again won't give me any specific product or a typical sensor that worked with my microprocessor. Anything here would have helped, and image would be a top answer for me because that could have helped me visually match a sensor that was a typical use case verses something that was extraneous. This being a double-edged sword due to the high chance of companies coming in and promoting their product over another is a good reason for this, but it seemed very frustrating as a researcher that I couldn't see a working system and how it performed. Lastly it couldn't give me any information on what a modern weather station uses specifically, it gave me a general idea and reiterated the sensor types but no specific makes and models.

In the end, the selection process using ChatGPT was mediocre. I would rate its performance a 6/10. This being because it was able to give lots of types of sensors even if it was slightly overwhelming. But I clearly failed to stay within the parameters of the project and give me typical data to use as test conditions so that I could attempt to detect a hurricane. It really needs to expand its database to include images or helpful forum posts of real people using products so that researchers can have more reliable hands-on data about the sensors and their capabilities.

5.7 CHATGPT: Case Study 4

The fourth major piece of information that I tried to extract from ChatGPT directly related to our project of the hurricane shutter and detection system was the motor choice. Specifically what motor would be good for the application and the different types of motors that are on the market in general. It both showed advantages and disadvantages when it came to picking the motors.

The advantages came from ChatGPT's plethora of options when it came to motor types. These included DC motors, AC motors, stepper motors, linear motors, brushless motors, and universal motors. I was familiar with most of the basic types of motors from my worldly experience but a couple of the more complex or lesser-known motors stumped me and I was able to get a basic idea of how they operate and how to possibly use them effectively. The biggest curve ball ChatGPT threw at me was the universal motor, I had no idea what it was and how it could be used or what its typical use case was, but it was able to explain that it was a motor that worked on both AC and DC power. It did have some notable drawbacks like being very inefficient, but I was able to confirm this by gaining knowledge by asking around to more experienced electrical engineers and a quick search from their competitor google. I also learned that AC motors can be synchronous, and induction based plus their types of use cases. Furthermore, I expanded my basic knowledge about linear motors and stepper motors. There use cases being rather different to the other types but noticing that a stepper motor is just a fancy type of DC motor that is more precise. And the linear motor can use more complex methods of driving itself like piezoelectric effects. ChatGPT summarized the main differences of the motors as efficiency, torque, speed control, and cost.

The disadvantages in this case were plentiful and wide ranging. When it came to driver circuits that paired well with the motors ChatGPT really struggled even after trying to convey to it the application I was trying to use it for. It also was unable to give a basic circuit diagram to help me understand how to integrate it with respect to a microprocessor and its voltage limits. After furthering my research with motor choice in mind I noticed that ChatGPT was missing a key part that most microprocessors can't run all types of motors due to not only the lack of raw power needed to provide them but the ability to produce the correct signal to control aspects like duty cycle and frequency. The results when researching motor types were good like I explained previously when it gave lots of options, some that I hadn't even heard of before but again there is a delicate balance to give long lists of options. This did seem somewhat overwhelming due to the raw number of options.

In the end I would say that ChatGPT did a pretty good job despite its shortcomings in some respects. I would rate it a 6.5/10 in the motor choice category. I gave it that score due to its great ability to bring up lots of options even though it might seem overwhelming for a basic researcher. I also liked how it was able to give a quick description about what each motor does and a typical use case. I again didn't like that it was not helpful when trying to pair it with a microprocessor and its inability to alert me of the need of a driver circuit to fix this problem theses were all discovered later after finding other competitor resources that were able to give me audio and visual examples to further my knowledge. Lastly its inability to explain that certain motors just can't be driven by certain microprocessors due to the processors' inability to produce the driving output.

5.8 CHATGPT: Case Study 5

The fifth major piece of information that I tried to extract from ChatGPT directly related to our project of the hurricane shutter and detection system was the screen choice. Specifically what screen would be good for the application and the different types of screens that are on the market in general. It both showed advantages and disadvantages when it came to picking the screens.

The advantages of having ChatGPT came when getting mass knowledge about different types of screens and some of their benefits and downsides. It gave some suggestions like ePaper or electronics paper, LCD or liquid crystal display, OLED or organic light emitting diode, dot matrix and segment displays. Most of these I have known about for years, and it was simply re explaining things I already knew. The new type is a dot matrix. This was an interesting suggestion seeing as it technically would work for my application, but it would introduce a layer of complexity that the other displays didn't have. The complexity comes when trying to display text. The programmers, or in this case my team, would have to individually program each letter and number we want to display since the matrix doesn't come with a library like the LCD, OLED. and segment came with. It did help me confirm my idea that the LCD display was a perfect mixture of low power consumption, color accuracy, customizability, and screen size. It was also able to confirm my knowledge about ePaper, this is a very new technology that has very low power consumption, but its use cases include a set it and forget it principle. This is far from what we desire since most of our data will be collected in real time and continuously displayed to show the current wind speed, humidity, temperature, and barometric pressure. Lastly it confirmed the OLED was a semi good option but was far beyond the color accuracy and power consumption allotted to this portion of the project even though we could have upgraded its graphics.

The disadvantages are when you ask it for specific products and how they can integrate into our system plus real-world examples. Again, it fails to provide specific products for my application. This was extremely frustrating seeing that there were a million different displays with slightly different features. It also got confused and started giving me information about touch screen displays that I never even mentioned I liked or that I desired in the project description. It again also lacked any way to properly prove that any of the types of displays worked with my desired microprocessor or any microprocessors for that point I tried giving it more general processors like Arduino and Raspberry pi and it still struggle d to give legitimate answers that weren't just high-level conceptual ideas. Lastly it could link me to any real-life examples like YouTube videos showing that a specific display is known to work with a microprocessor or a forum page of enthusiasts that show decent understanding of the product.

With that all being said I would say that ChatGPT is acceptable when it comes to assisting me in picking a screen. I would give it a 5.5/10. I came to this score by considering its advantages of being able to explain at a high level what the screen types were and some general use cases. I also considered all the disadvantages like the inability to get me to a real working example or a forum post of experienced individuals that could help me figure out my situation. Lastly it could help me get a circuit diagram of the screens and show me how the processor could integrate into my specific microprocessor or what types of interfacing types I should be expecting to use in my system.

5.9 CHATGPT: Case Study 6

The sixth major piece of information that I tried to extract from ChatGPT directly related to our project of the hurricane shutter and detection system was the shutter choice. Specifically what shutter would be good for the application and the different types of shutters that are on the market in general. It both showed advantages and disadvantages when it came to picking the shutters.

The advantages started with the ability to accurately inform me about all the different shutter options that are currently used and some specifications plus applications. The options it gave me for available options today were accordion shutters, roll-up shutters, shaker shutters, Bahama shutters, storm panels, and impact resistant windows. Most of these I have seen and worked on before, but the last two options piqued my interest, seeming that storm panels are not exactly shutters and neither are impact resistant windows. It gave me a decent description after double checking its facts from a known source and these are options that most home-owners consider when shopping for hurricane shutters but aren't really shutters themselves. It was able to confirm by knowledge of the other types of shutters including accordion shutters, roll-up shutters, shaker shutters, and Bahama shutters. It also gave a weird warning that I should check local building codes even though I haven't asked it about purchasing or hanging them only the types and their benefits and downsides. It also summarized the major aspects of the shutters that came down to a few properties just like the ones I came up with when researching them on my own. They included but were not limited to strength, cost, repairability, visual appeal, and complexity. It also helped me confirm my idea that my specific design, which is a hybrid of all the types, is a good idea because of all the numerous benefits that the system will have due to the proper shutter type choice.

The disadvantages were overall not too bad in this section. It has never given me a specific product which I believe is due to ChatGPT being more aimed at information instead of product placement like its competitors Google and Bing. This again causes some frustration because the best type of research is one that leads you to a working prototype that you can learn from. This hands-on material area is a crucial part of improving these search results to inspire confidence in the high-level broad information that it spits out. Then backtracking to the weird sets of warning that came up when doing basic research on the types of shutters. I never even alluded to the fact that I was going to purchase to install the se myself and it had already given me loads of warning about checking with local building codes and specifications to ensure optimal safety. Plus, it also only suggested that a professional install these products which is understandable for the more complex roll up shutters, but it is very disingenuous and disheartening that it seems to be pushing a non-DIY agenda.

Largely in this section of my ChatGPT research the results were pretty good if I overlook some of the controversial problems with the results. I would give this research an 8/10. This is based on its sweeping knowledge and safety priority even if it seems a little too overbearing for an average adult. It was able to give me general knowledge of the types and keep me heading down the right path. The small problems still occur when trying to nail down a product or a real-world example of the system in action. Plus getting datasheets was challenging due to it being a little apprehensive about intellectual property and not infringing on that.

10 Administrative Content

10.1 Budget

This project is not sponsored by any outside commercial or academic organizations and care must be taken to keep the development costs to a minimum for the storm shutter project. $500 is the goal for development of the automated storm shutter project allowing costs to be spread among the members at $125 per member. The project will require at least two custom PCB's, various sensors, one or more motors, at least one micro controller, a demo window, and a shutter.

Part selection is currently being researched. Once the proper technologies are chosen and vendors with the lowest cost are found a Bill of Materials will be created and the budget will be reexamined. An initial estimate of the prototype costs is shown below. Note that some parts of the project such as the Pi4 mentioned in the software flow are already owned by a member of the group and do not need to be purchased. The miscellaneous funding is the greatest to allow for reallocation of funds to remain flexible as the design matures. As the development of the window shutter project continues the budget and line items will be updated with the new totals. The budget finalization is contingent on the finalization of component selection. Once the component selection is complete a Bill of Materials can be generated, and components will be ordered.

Table 28: Estimated Development Costs:	
Item	Cost
PCB	$60
ESP32-WROOM-32UE-N8	$3.30
Anemometer	$48
Sensors	$80
Batteries	$21.04
Window Shutter assembly	$100
Motors	$50
Miscellaneous	$137.81
Total: $500	

10.2 Milestones

Table 29: Milestones		
Description	Completion Week	Status
Choosing Project.	1	Complete
Initial project requirements documentation	3	Complete
Technology selection	4	Complete
Research	5	Complete
Design constraints	6	Complete
60 page draft	7	Complete
Part Selection	8	In Progress
Schematic Capture/Software	10	In Progress
PCB layout/Software	11	Not Started
Final 120 page document	12	Not Started
Integrate MCU with sensors	14	Not Started
Integrate MCU with motor controller	15	Not Started
App integration with MCU/sensors/motors	17	Not Started

Final assembly and testing	20	Not Started
Debugging	27	Not Started
Final Report/Demo	28	Not Started

10.3 Work Distributions

It is important when working in a group to strike a balance between playing to each other's strengths and allowing every member to attempt new things and develop new skills. It is not uncommon for an Electrical Engineering student to feel physically ill when assigned a programming project or for a computer engineer to look at you strangely when talking about signal integrity. Many students don't have engineering experience outside of the classroom, but every team member has experience in some area unique to them. Senior Design is not only about delivering an impressive demonstration of technology and design. Senior Design is also about having a story to tell potential employers about the friends you made and the challenges you overcame as a group.

Group 6 contains four members: Andrew D'Aquila majoring in electrical engineering, Spencer Spalding majoring in electrical engineering, Antonio De Leon majoring in electrical engineering, and Aidan Dion majoring in computer engineering. Andrew comes from a strong mechanical design background even having designed a door that is currently on board the ISS. Antonio also comes from a strong mechanical background having been a tech at a Toyota dealership for 12 years. Aidan's strengths are software development and computer hardware, having built his first computer at 12 years old as well as having real world experience with embedded systems at a co-op/internship. Spencer has an interest in electronics and has some real world experience with PCB design at an internship.

Table 30: Summary of Self Perceived Strengths and Weaknesses

Team Member Name	Strength	Weakness	Constraints	Contribution
Andrew	Drive/Precision	Programming	Time	Hardware Design
Aidan	Strong Software Knowledge	Weaker Hardware Knowledge	Busy with work/life	Software Design
Spencer	Embedded/Circuit Analysis	No Object Oriented Programming	Work, Other Classes	PSU, Firmware, PCB

Antonio	Hardware/Testing	Software	Work schedule, distance	Hardware Design

Some members would like to focus on certain areas of the project and others would like a blending of many different aspects. Based on the strength's weaknesses and desired contributions of each team member, both the hardware and the software of the automated storm shutter project will have dedicated team members who are passionate about their respective area of interests. The work distributions listed below are meant as a guide and based on everyone's strengths and interests. The work distribution is not written in stone and can and should be flexible. For instance, If Andrew is busy with classes and decides he won't have time to finish the schematic capture for the motor driver and Antonio is busy as well, the motor driver can be given to any free team member or redistributed between the entire team if possible. The work distributions are a rule of thumb to keep everyone focused in one area to become a subject matter expert instead of a jack of all trades master of none.

Table 31: Summary of Work Distributions

Component	Primary Team Member	Secondary Team Member
MCU	Aidan	Everyone
Software		Spencer
Barometer	Antonio	Andrew
Temperature Sensor		
Screen	Andrew	Antonio
Speaker		
Shutter		
Motor		
Power Supply	Spencer	Aidan
Anemometer		

10.4 Discussion of equipment and facilities

When it comes to assembling and testing the design the team may make use of the senior design lab in room Engineering building 1 room 456. The senior design lab comes equipped:

- Tektronix Oscilloscopes
- Tektronix Dual Arbitrary Function Generators
- Tektronix DMM 4050 Digital Multimeters
- Keithley 2230-30-1 Triple-Channel Power Supplies
- Dell Precision 3420 Computers
- SMD Rework Station
- Soldering and Desoldering Stations
- Digital Microscope Inspection Station

[S17]

This equipment will be useful in senior design 2 when the assembly, testing and debugging phase begins.

Only one member lives near the UCF campus. The other 3 members are 1-2 hours away from the UCF campus. One skill learned because of the Covid-19 pandemic was the skill to perform classwork and job functions from home. The inability to meet often on campus will have to use software like Zoom for face-to-face synchronous meetings and discord for group communication and to keep a record for communication.

The UCF senior design lab also provides free test equipment that each group can check out to do at home testing and debugging. The test equipment includes:

- Digilent Analog Discovery 2
- BNC adapter
- Impedance analyzer
- 2 Oscilloscope probes
- Mini Grabber Clips
- Digilent large breadboard & mini breadboard
- Breadboard breakout
- BNC alligator adaptor
- Hantek 2d72 3 in 1 Oscilloscope, DMM, function generator

Figure 04: Digilent Analog Discovery kit Provided

The Digilent Analog Discovery 2 is a powerful piece of test equipment that includes a function generator, 2 channel oscilloscope, DMM, logic analyzer, spectrum analyzer, and impedance analyzer all in a small package that communicates through USB to the Waveforms software suite on your PC.

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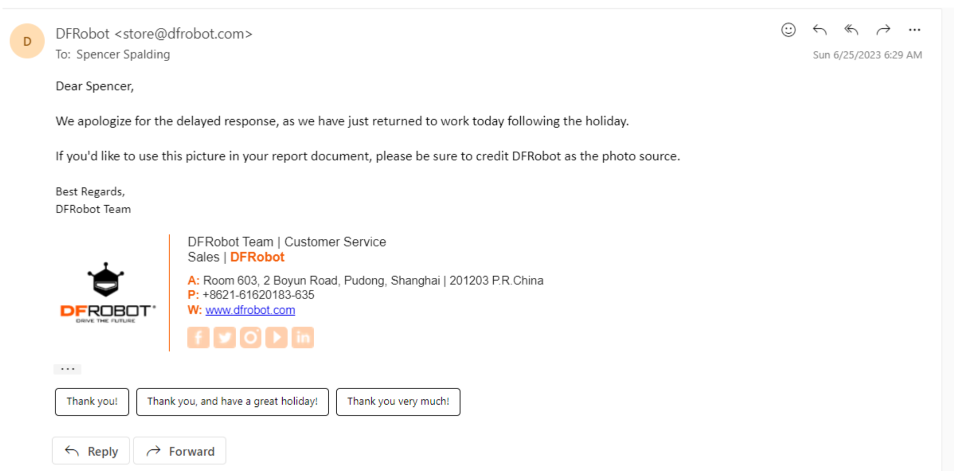
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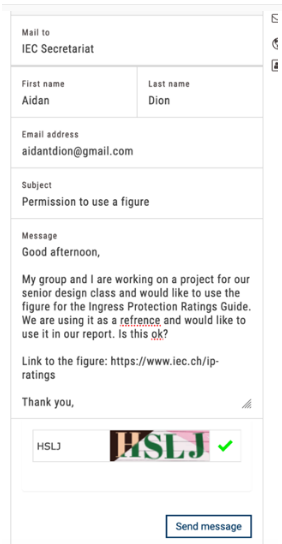
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