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Date:
02, August 2016

Game Feeder Cam

Senior Design 2
EEL4915
Term:
Spring/Summer 2016

Contents

1.0 Executive Summary

Before the hunting season begins, many sportsmen spend time out on their hunting property scouting for possible game activity in preparation for the upcoming season. This process of scouting eliminates inactive areas of the property ensuring better odds that the placement of ground blind or tree stand in that area will produce an opportunity for a kill. The typical sportsmen scouting technique involves providing feed to attract game to an area and a way to document game activity in the area. Usually this will require a game feeder and a carefully positioned game camera to document activity along with time of day. During the duration of this equipment being on the lease, the sportsmen must keep batteries replenished, replace feed and check cameras for activity using a picture viewer.

If there was an integrated system for scouting game provided to the sportsmen that would both feed and document game activity, the amount of equipment to buy and carry out onto the property would be decreased. Then, with improvements to the available camera systems, programming, and the power system the end result would be “a better trap”. Improvements could include wireless picture transfer pictures to reduce the need for a media storage device or picture viewer, a reduced number of batteries to ensure an easy time remembering quantity and size to replace and lastly to allow for better water proofing as well as user friendly controls.

As it is now, there are many products on the market which try to fulfill the scouting needs of the sportsman individually. Most outdoors stores carry a variety of game feeders, game cameras, and mobile handheld picture viewers. The game feeders bought at a basic level have either analog or digital timers. There are additional add-ons for the user to purchase and install on the game feeders such as solar charging panels. Game cameras are also available on the market with a variety of options, although most record only what is located in 180 degrees field of view. This leaves the avenue of approach of the game approaching from behind the game camera a mystery. The latest trend among sportsmen is to purchase picture viewers which eliminate the need to bring a replacement SD card or laptop computer to retrieve game camera pictures.

The Game Feeder Cam (GFC) fulfills the need for a scouting system that integrates the feeder, camera and picture viewing medium. The GFC provides a feeder, greater camera area coverage, wireless picture transfer and mobile application settings. Text message alerts are sent to the sportsmen to notify them of the number and date/time stamp of pictures taken by the GFC. This prevents the need for a trip if there has not been any activity, which saves time and travel expenses. Custom features are accessed using the app. The transfer of pictures is also conducted through this application.

2.0 Project Description

The project description covers the personnel information, motivations for designing the GFC, the objective of the GFC, the goals needed to meet and acknowledgments to the outside personnel who helped in the making of this product.

2.1 Personnel

The GFC team consists of two computer engineers and two electrical engineers. At the first group meeting the members discussed the project and assigned responsibilities for each component of the project. Anthony and Daniel, computer engineering majors, focused on software design of the project while Richard and Joseph will focused on electrical component design. The component housings, feeder and feeder stand were designed and assembled by Richard because of his knowledge and experience with game feeders and game cameras. Although the team divided the project into parts to work on individually the project is interlaced so component decisions were made in parallel to ensure proper compatibility.

2.2 Motivations

Before reaching senior design, Richard spent his off time from school in the fall hunting. The GFC idea originated during these times while sitting high in a tree stand hoping the pre-season scouting would pay off. After getting the idea vetted as a senior design worthy project, the idea was posted to a group internet page for the senior design class of spring two thousand sixteen. It piqued the interest of three additional students sharing similar interests and a group was formed.

The usual hunting season begins months before the season opens, which begins with scouting. Scouting typically consists of setting up feeders that dispense feed and cameras to record the activity at the feeder. This enables the hunter to see firsthand the activity around the area intended to hunt in order to reduce time wasted waiting in an area unpopulated by the target species. This set up will require the feeder, mobile picture viewing device and a camera that will capture animals coming to the feeder from the front of the camera. The camera has a secure digital (SD) card that is removed and inserted in a picture viewer or replaced with a new SD card. A camera, normally powered by nine ‘C’ cell batteries will also need its batteries replaced periodically. Then the feeder requires battery replacement which is normally one six or twelve volt battery. The feed will also require replenishment at least once a month.

The motivation for this design was that of having experience with the products currently on the market and the desire to improve upon those products. When checking on the feeder and camera, sometimes weekly, the sportsmen must remember to carry with him an extra SD card, picture viewer and or laptop, camera batteries, feeder batteries and corn.

After an hour or more drive into the backcountry and walking a mile through the woods to the feeder and camera from the main entrance of the hunting property, forgetting one of these items would make any sportsman ponder about an easier method of knowing whether there was viable game in the area for hunting.

2.3 Goals and Planned Objective

The objective is to design a standalone system that combines both a game feeder and a game camera.

The goals are to improve upon what is currently available on the market by replacing the typical analog or digital feeder timer modules with an integrated mobile application to control both the feeder motor and the camera. The application will allow the user to view, transfer and delete the pictures taken on the game camera. After combining a game feeder and a game camera the size and portability should be similar to that of currently available fifty-five gallon drum feeders on the market. To make the GFC portable it will need to be modular for transportation to and from hunting locations. The power system will be simplified as to eliminate the need for carrying large amounts of replacement batteries. Also the GFC will have a solar charging system to extend the time between battery replacements. The usability of the GFC needs to be user friendly or it will lose a section of the market that would stay with the simple to use analog systems. The assembly and disassembly of the GFC should be easy, requiring a minimum number of tools to assemble.

2.4 Acknowledgements

Keith Kelly, an avid hunter of twenty years, gave input to the features that he would like to see to on the GFC as well as improvements to the features already offered. Mr. Kelly also gave insight to the average battery lifespan with and without solar panels which was between twenty to thirty days. Also mentioned was that if the GFC was to implement a greater camera area to identify the direction in which the picture was taken. The input was based on both hog and deer hunting experience. In addition to input for the project Mr. Kelly will be donating his time and metal fabrication experience to weld the feed container stand together. Also Karl Clements, an electrical engineer at Mears Transportation donated his time and personal facilities for the construction of the GFC stand as well as feedback on design ideas and problems.

3.0 Project requirements and Design Constraints

Project requirements set by the team, design constraints, finances and a timeline for the project will be covered in sections below.

3.1 Problem Statement

The GFC as discussed above consists of an integrated game feeder, game camera and wireless capabilities. Each piece of the GFC has its own subsystems which will be broken down and discussed in detail below. Chapter five will cover the thought process and information gathered to produce an improved integrated system that will stand out among all other available units. Research was conducted to find the best possible components while keeping cost reasonable to that which when combined make up the basics of which the GFC consists of. The main problems discovered in development included wireless signal in remote areas as well as communications between feeder, camera and the weather gathering sensors. Also because of the environmental conditions the GFC will be exposed to, the electronics placement needs to be carefully considered to avoid corrosion or water damage.

3.1.1 Design Specifications

The design specifications that are taken into account are hardware, software, physical and structural. Not to be confused with standards or constraints but more so guidelines for the team to follow and have a better focus towards completion

3.1.1.1 Hardware Specifications

- Components must run off twelve volts or less.
- Game Feeder should remain operational for at least a week.
- The motor should have multiple feed dispensing settings.
- All electrical components should have an off switch for safety.
- Mobile phone should be able to communicate with Feeder

3.1.1.2 Software Specifications

- Source Code should be written in possibly C, or C++.
- Programming should not exceed given memory space on chosen Microcontroller
- Pictures and environmental conditions are uploaded on mobile application through Bluetooth.
- Mobile application is used to control feeder settings

- Code should be kept on an easily accessible repository and properly maintained

3.1.1.3 Physical Specifications

- Sensors should be on the lower part of feeder.
- Exposed wiring should be kept to a minimum
- Encasing for microcontroller should be weather proof
- Approximately one to two pounds of feed should be dispensed at a time
- All components should be easily removable for transportation.

3.1.1.4 Structural Specifications

- Frame should be stable and able to withstand maximum feed capacity.
- Must include a ladder and platform for replenishing feed.
- Feeder should be capable of withstanding poor weather conditions.

3.4 Realistic Design Constraints

Below are the listed related realistic design constraints pertaining to the main functions of the GFC project. Functions within the constraints include:

- Budget
- Wi-Fi and remote control
- Cameras
- Wild Life regulations

The following sections will define the ABET Constraints and ANSI required standards.

3.4.1 Economic Constraints

The economic constraint of the project is the allocated budget of roughly fifteen hundred dollars. It is expected that some of the subsystem parts are going to be donated. For all else the group would have to split the cost of all remaining parts.

Ideally, more than the estimated budget amount will not be needed to complete the GFC project thanks to the donated parts that will be received. The two main components that present the highest cost are the three hundred sixty degree camera system and the solar panels system.

This project is to create a new version of game feeder systems that integrate the multiple parts that are currently sold separately into one. This product is mostly directed towards hunting enthusiasts. This being said, this project needs to be practical, convenient and relatively inexpensive as opposed to buying the parts separately in order to encourage sales. Making this product as inexpensive as possible will greatly benefit the project budget as well as being highly beneficial to the target consumers purchasing and performing maintenance on the finished product.

3.4.2 Environmental, Social, and Political Constraints

The game feeder is going to be built for outdoors and hunting enthusiast. Having said this there are possible environmental consequences to keep in mind while designing the game feeder. The main concerns of this device are going to be noise pollution, altering wildlife patterns, over hunting, and possible environmentally harmful waste. However the feeder system will run only on electricity that will be mainly powered by a renewable energy source. Therefore at least when it comes to this will there will be no worries about environmental pollutions.

There will be no direct water or environmental pollution from the system. A possible problem that may come from the game feeder is the disposal of batteries or replacement parts therefore the responsibility would technically rest solely on the consumer. Still one thing that could be focused on, for example, is the quality of the batteries that would need less replacement and thus avoiding any potential pollution. Another environmental issue would be how the game feeder would affect the feeding patterns of the surrounding wildlife potentially harming the local ecosystem.

Being made out of electric components there is always a risk of fire, with the hunting environment being in the outdoors there are plenty flammable elements such as dry leaves or branches that could start a forest fire. Endangering any nearby animals not intended to be hunter or people as well. Thus any energized components should be kept hidden and insulated at all times. Another fire hazard would be over heating of any component so the game feeder components need to have a decent heat dissipation in order to avoid any dangerous temperature that could ignite a fire

As far as social constraints there are the groups of people that are openly against hunting. Such groups consider the killing of animals for sport as frowned upon.

For political constraints since the intended use of the game feeder is for hunting the consumers are mainly going to have the required age and licensing for the sport. The project is mostly self-funded with the exception of some donated parts which means there are no contracts involved. For the main controller board, the Arduino software environment will be used. So if the decision to market this product is made, permissions from this company will have to be made.

The game feeder is intended to use outdoors in the deep woods and is not intended to be used for invading the privacy or disturbing the peace of others. Responsibility of avoiding such things rest ultimately with the consumers. In addition if the game feeder ever becomes a marketable product it will include the necessary safety instructions and warning labels for any sharp or moving parts.

3.4.3 Health and Safety Constraints

As Stated above in order to avoid any possible injury measures, like including safety and handling instructions as well as applying warning labels to any sharp or moving parts. Any of the aforementioned parts would also need to have some type of guarding to avoid injury. The batteries will run on approximately twelve volts which should not be harmful to handle by a person. Nonetheless a master turn on and off switch can be implemented on the design to avoid electric shock.

There are no parts of radioactive properties. In addition there are no products that have form of toxicity when handled correctly. The only possibility of toxicity is if a consumer uses tools to physically crack open a battery, which is highly unlikely

3.4.4 Manufacturability and Sustainability Constraints

Once the project is complete there will be instructions as of how to mount the game feeder together as well as the necessary layouts and connection for any circuit board replacements. Instructions should be simple enough that someone without any experience in engineering could order and replace any broken parts. The game feeder system is also designed to be completely self-sustainable running off of solar powered electricity and only to be required to be re-filled with feed periodically.

3.5 Estimated Budgets and Finance Plans

The GFC will primarily be funded by Richard Kelly because of his intention to keep and field the product post-graduation in order to test and gather data to improve upon the design for possible future production. According to rough estimates annotated in Table 1 –Electronic Component Costs and Table 2 – Materials for construction costs below which lists the quantity and unit cost of the necessary components and materials, the estimated total design project expenditure was approximately $1512.45.
In the Table 1 - Electronic Component Costs below all components that have been purchased or will be purchased. The Arduino Mega2560 development board, breadboard, jumper wires, and GSM battery, will not be included in the

final project but are necessary for prototyping the component to ensure proper integration before finalizing the design. The PCB board count includes the MCU, weather station, camera system, motion sensors, and all PSU boards projected to be created for the GFC. The PCB cost estimate includes board printing and components. The cost of the DC motor is not reflected in the table below because it was reused from the feed distribution system housing which is listed in Table 2.

Item	Quantity	Unit Cost	Total (with tax)
Solar panels	1	Free	Donated
PCB Boards	8	N/A	$737.59
Motion sensors	4	$20.36	$81.44
HTU21D-F Temperature & Humidity Sensor	1	$9.99	$10.69
MPL3115A2 - I2C Barometric Pressure/Altitude/Temperature Sensor	1	$13.20	$14.12
12 volt Battery	1	$19.99	$21.39
Weatherproof TTL Serial JPEG Camera with IR LEDs	1	$54.95	$58.80
MicroSD Card Breakout Board+	1	$7.50	$8.03
SanDisk Ultra 32GB Micro SD	1	$10.69	$11.44
Arduino Mega2560	1	$30.99	$33.16
400-Point Experiment Board	1	$5.07	$5.42
Jumper Wire Package	1	$6.87	$7.35
Adafruit FONA 808 GSM/GPS	1	$49.95	$53.45
JY-MCU Bluetooth Module	1	$9.99	$10.69
Servo Motor	1	$25.00	$26.75
Wiring	1	$44.00	$47.08
Antennas GPS	1	$3.95	$4.23
Antennas GSM	1	$2.95	$3.16

GSM SIM card	1	$9.00	$9.63
GSM battery	1	$9.95	$10.65

Table 1 – Electronic Component Costs

The remaining costs fall under materials for construction seen below in Table 2. The welding and metal fabrication were donated but the quote received from a local welding and metal fabrication shop was three hundred dollars. The acrylic housings will be built by the GFC team and no estimates have been found on the cost that would be incurred if the work was outsourced. Money was saved on the fifty five gallon drum by buying it used at a local pet store for fifteen dollars.

Item	Quantity	Unit Cost	Total (with tax)
55 Gallon Container	1	$15.00	$16.05
Power Systems Housing	1	$15.03	$16.08
Feeder Housing (motor and disc)	1	$59.99	$64.19
Angle Iron ¼"x20'	4	$25.00	$100.00
Feeder Stand Poles 1"x5'	4	$19.31	$82.65
Spray paint	12	$3.97	$50.97
Square steel tubing 1"x20'	1	Free	Donated
Sheet steel 4'x8'x1/8"	1	Free	Donated
Weather System Housing	N/A	$25.00	$26.75
Silicon	2	$4.97	$10.64
Camera System Housing hardware	N/A	$24.00	$25.68
PVC tube ½"	17'	$0.59	$10.30

Table 2 – Materials for Construction Costs

3.6 Scheduling Concerns and Time Limitations

Due to the shortened summer term for final design and assembly, much of the prototyping was done in the spring term to allow for any unforeseen problems. By planning ahead, the group was able to reconvene and choose alternative parts and viable solutions rather than eliminate features.

3.6.1 Milestones

Semester 1:

- Learning and understanding how to program with the Android SDK
- Learning Bluetooth communication between app and MCU
- Research on Solar energy power system
- Begin designing android phone application
- Gather all Hardware and Software components and begin prototyping

Semester 2:

- Finalize Android Application Development
- Finalize and have PCBs built
- Integration of all hardware components into feeder design
- Establish Bluetooth and Cellular communications with the feeder, camera and weather systems.
- Successful integration of mobile application.
- Feeder container and stand acquired and assembled
- All housings mounted to the main system

4.0 Standards

Standards are the design specifications that are to be adhered to during the design process that ensure a high level of quality and a guideline for creating new products. For engineering and technical products, the Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) is the organization responsible for creating these global standards.

4.1 Standards

For wireless communication to transfer data and images, Wifi, Bluetooth, and 3G/4G are the forms of communication considered. Wifi must adhere to IEEE 802.11 standards for data communication. The newest standards released for Wifi technology are the 802.11n and 802.11ac standards, with the 802.11ac technology having a much larger range and data transfer rate. Bluetooth communication must conform to the IEEE 802.15.1 standard for Wireless Personal Area Networks (WPANs). For 3G/4G communication, the standards are set by the International Telecommunications Union-Radio communications sector (ITU-R). These standards are meant for mobile communication and both standards were improved highly over their 2G counterpart.

	Bluetooth Classic	Bluetooth Low Energy (BLE)	ZIG-BEE	Wi-Fi
IEEE Standard	802.15.1	802.15.1	802.15.4	802.11(a,b,g,n)
Frequency (GHz)	2.4	2.4	0.8,0.9,2.4	2.4 – 5
Max Bit Rate (Mbps)	1 – 3	1	0.25	11(b),54(g),600(n)
Max Range (m)	10 – 100	50	10 – 100	100 – 250
Power Consumption	Medium	Very Low	Very Low	High
Battery Life	Days	Months to Years	Months to Years	Hours
Network Size	7	Undefined	64,000+	255

Table 3 – Wireless Comparison

Shown in Table 3 is the comparison of IEEE standards for 802.15.1 (Bluetooth), 802.15.4 (Zig-bee), and 802.11 (Wi-Fi). Wi-Fi has the largest bit rate and max range but also has the highest power consumption leading to a lower battery life in the system. This is a large consideration when choosing the wireless communication means when trying to conserve battery life and allow the feeder to operate for as long as possible before using up the battery power, even with utilizing solar power in charging the batteries.

GPS information and the text alert features will be achieved through the use of a GSM module. The Global System for Mobile Communications (GSM) module operates under the GSM standards set forth by the European Telecommunications Standards Institute (ETSI). This protocol standard was developed in order to describe the protocols for 2G digital networks utilized by mobile cellular devices. Under GSM standards, a GSM must operate in the intended frequencies shown in Table 4 - GSM Frequency Bands.

GSM Frequency Bands		
Band	**TX (MHz)**	**RX (MHz)**
850	824 – 849	869 – 894
900	880 – 915	925 – 960
1800	1710 – 1785	1805 – 1880
1900	1850 – 1910	1930 - 1990

Table 4 – GSM Frequency Bands

For the solar power system, construction standards are set by the Solar America Board for Codes and Standards (Solar ABCs). This is a collection of the different codes and standards on solar energy systems that is funded and endorsed by the U.S. Department of Energy. This organization includes codes and standards for safety and design set forth by ASTM, IAPMO Standards, the International Code Council, International Electrotechnical Commission, IEEE, the National Fire Protection Association, SEMI, the Solar Rating and Certification Corporation, and others.

In the software implementation, both open source code and original written code will be utilized. For the android application coding, an official set of standards and rules are given by android for acceptable applications. This list of standards is clearly laid out on the android website in the contributing code section. Standards and rules set forth by Apple in writing Swift code are outlined on the developer section of the Apple website.

Specific standards and rules are laid out regarding the hunting of game using feeders to bait game. These standards and regulations vary by state and the hunting of game is restricted to hunting seasons and only certain game. Only specific methods of hunting game are allowed and a hunting license must be issued in order to hunt game of any kind with the exception of wild hogs. Wild hogs may be hunted year round without a license and with no size or bag limits with owner's permission. The daily restriction for hunting game is from half hour before sunrise until sunset. For other game, the regulations in feeding game for the sake of hunting in Florida are as follows:

- Non-migratory game may be hunted on private lands in proximity of game-feeding stations that are maintained with feed throughout the year, provided the feeding station has been maintained with feed for at least six months prior to taking game in proximity thereof.
- No processed food products (i.e., any food substance that has been modified by the addition of ingredients or by treatment to modify its chemical composition or form or to enhance its aroma or taste) may be used at game-feeding stations in any area of the state with an established bear season. This includes: food products enhanced by sugar, honey, syrups, oils, salts, spices, peanut butter, grease, meat, bones or blood; candies, pastries, gum and sugar blocks; and extracts of such products but does not include scented sprays or aerosols and scent powders.
- Pelletized feeds, flavored corns or other grains and mineral or vitamin supplements specifically and exclusively produced or marketed for feeding deer and commercially available feeds specifically and exclusively marketed for feeding swine (hogs) may be used at game-feeding stations statewide.
- Wild turkey may not be taken if the hunter is less than one hundred yards from a game feeding station when feed is present.
- Bear may not be taken if either the hunter or bear is less than one hundred yards from a game feeding station when feed is present.
- The intentional placement of food in a manner that attracts coyotes, foxes or raccoons and that is likely to create or creates a public nuisance is prohibited.
- The intentional feeding of bears is prohibited.
- The intentional placement of feed in a manner that is likely to create or creates a public nuisance by attracting black bears, foxes or raccoons is prohibited. In addition to normal agricultural harvesting or planting methods, mourning and white-winged doves may be hunted over agricultural crops that have been harvested or manipulated and over natural vegetation that has been manipulated.

5.0 Research

Research was conducted on all components required to build the Game Feeder Camera. The information gathered helped narrow down component choices using a ratio of cost vs performance. All research was documented in order to provide a reference for future production where funding may increase, which would allow an upgrade to performance.

5.1 Similar Products

While researching similar products, it was discovered that only one idea closely resembling the GFC located on a website called https://forsalebyinventor.com. According to the information on the website the idea is for sale and there is no current prototype provided on the page, just a CAD representation of what it would look like. The design on this page has a combination gravity and mechanical feed distribution system where at a prescribed time, feed trough doors on the side of the barrel would open allowing game to come by and feed. This system also addressed the problem of three hundred sixty degree camera coverage by implementing four separate cameras and it also utilizes a mobile phone application. Besides this one product, there are game feeders and game cameras available for purchase separately on the market.

5.1.1 Game Feeders

The typical feeders available on the market consist of a feed container being of either plastic or metal construction. Feed capacity of the containers vary depending on the length of time the sportsmen needs the feed to last. Most of the containers are elevated of the ground while there are a few low end systems that sit on the ground. There are two main types of feed distribution on the market purely gravity fed and a combination of mechanical and gravity. The feed distribution systems that utilize the combination method have either an analog or digital system to trigger either food to drop or to disperse. Prices range from about twenty seven dollars for an American Hunter five gallon hanging bucket feeder with a fifty pound capacity to eighteen hundred dollars for the Outback Wildlife Feeders Baby-Back one thousand pound capacity feeder. The feeders observed used either a six volt or twelve volt battery.

5.1.2 Game Cameras

There are many types of game cameras on the market that range in price from about forty-five dollars for the Huten Outdoors GSC35-50 infrared black flash game camera to the Reconyx UltraFire WR6 white flash LED eight megapixel game camera for six hundred dollars. Using the reviews for the best game cameras for 2016, information was gathered on the typical megapixel range, flash, trigger range and batteries. The range for megapixels was found to be three to twenty. Trigger distances are from twenty to one hundred feet. Flash for the cameras included infrared lo glow, infrared no glow, and LED. Each of the flash types utilized different quantities of bulbs. The battery types ranged greatly in quantity and size, which included AA, C and D cell batteries. The typical game camera shown in Figure 1 -Moultrie Game Camera looks different from the game camera utilized on the GFC.

Figure 1 – Moultrie Game Camera

5.2 Power System Research

The Game Feeder main power source is going to be from a six to twelve volts rechargeable battery. This battery will be connected to a circuit board that will convert all the voltage for the different devices in the feeder. Once set the feeder is expected to maintain operation from a few days if not weeks in order to accomplish this the battery will be recharged by two solar panels. The energy collected in the solar panel would also have to be stepped down in order to charge the battery properly. In addition, a programmable power source is needed for the motor that can adjust the voltage parameters remotely with the mobile application. That way the feeder can have the multiple dispensing options. Blocking diodes will need to be used on the solar panels in order to keep the current flowing in the correct direction. Bypass diodes will also be needed in order to bypass one panel from another.

5.2.1 Charging system

The Game Feeder system has to retain proper functionality over long periods of time despite little or no maintenance. Therefore, it requires a reliable charging system to ensure a maximum battery life. Due to the environment the feeder is going to exposed, the best type of power system would be solar. This means that the charging system has to be able to regulate the amount of power received from sunlight rays providing a steady charge for the battery without over charging it. Different charging systems along with their advantages and disadvantages will be discussed below.

5.2.1.1 Simple Charger

This charging system provides a constant voltage in order to charge the battery. The mayor advantage of this type is that it is fairly simple and inexpensive to design and build. However having a constant unregulated voltage source could damage the battery shortening its lifespan.

5.2.1.2 Fast Charger

This charger rapidly charges the battery by using control circuitry which will take advantage of the limited amount of sunlight during the day. The control circuitry can also protect the battery from overcharging. The problem with it is that this type of system tends to overheat.

5.2.1.3 Timed Charger

Timed chargers have preprogrammed charging times. However, this type does not protect from over charging because accurate predictions have not been made on how much the battery will be discharged versus how much it will charge during the day. This is due to the possible random feeding patterns of wild animals.

5.2.1.4 Trickle Charger

A trickle charger, charges the battery at the same rate that it discharges. This ensures a long battery life even with the battery being connected to the source for longs period of time. This system will be taken into consideration.

5.2.1.5 Smart Charger

This type of charger system monitors battery voltage, temperature and charging time. By doing this, the system can determine the best charge current at that moment. The system will also cutoff when the charging is complete. The only drawback from this system that is the most complex type. This is the system that will most likely be implemented in the feeder assembly.

5.2.1.6 Designing a Charge Controller vs purchasing one

When it comes to the solar charge controller of this project the most beneficial option is purchasing a plug and play solar charge controller. For example an online company called Genasun carries a controller that is compatible with lithium Ion batteries and use advance charging algorithms for approximately one hundred dollars. This controller also comes equipped with a smart maximum power point tracking technology that ensures that the battery gets the maximum amount of power from the panels no matter on the environmental conditions. However, since the budget is very limited the best option would be to research and design a smart charger implementation. It would probably will not be as powerful or as efficient as the ones in the market but as long as it meets the requirements and standards of the game feeder it will be enough. That way the total cost can be kept to a minimum. It will also make things easier for a manufacturing process in the future if the rights to the feeder design remain with the group.

5.2.1.7 Charge controller Options Conclusion

Based on the research done above about charging controllers the best route to go is with the smart charger. This will ensure that the battery is getting the most energy possible from the solar panels without causing any damage to it thus prolonging its life. In addition, a smart solar charge controller will be designed that will save a considerable amount of money. However if the smart charger becomes too complex to create on the allotted time, a trickle charger is another option to look into.

5.2.1.7.1 Smart Charger Design research

Now that the decision has been made to design a smart charge controller there are three types of technology that come into play which are the one to two stage diversion controller, the pulse width modulation controller, and the maximum point power tracking controller. The theory of how each one of them works will be discussed and then a conclusion will be reached on which one to implement in the game feeder system.

5.2.1.7.2 1 or 2 Stage Controller

Also known as voltage charge or diversion controllers are the simplest and most inexpensive of the smart controller. Basically they are made up on a set of relays to disconnect or divert the energy source when the battery reaches a certain point. Unlike the PWM and the MTTP charger these controllers do not provide any battery maintenance they simply monitor the battery voltage and trip once a certain level is reached then is kept off until they reach a lower voltage before reconnecting once again.

5.2.1.7.3 Pulse Width Modulation Charger

A pulse with modulation charger is a simple type of a smart charger that determines charging current by comparing the difference between battery voltage and charge set point voltages. In order to do this it uses a main control unit such as an Arduino board then according to this voltages it decides how to charge the battery and control the load. However it is not just by shutting the switch whenever the battery gets closing to its full charge. The controller determines the state of the battery and then sends the appropriate pulses by changing their duty cycles and frequency.

The main functions and benefits of this controller will protect the battery from overcharging by limiting the energy supplies as it reaches its maximum or in the case of an abnormal condition such as lightning or a short circuit. To prevent over discharge by disconnecting the battery if it gets critically low and to monitor the load power and energy. It does so with the use of multiple sensors just as voltage, current and temperature.

5.2.1.7.4 Maximum Power Point Tracking

Maximum power point tracking or MPPT, is one of the most advanced solar controllers available. MPPT compares the output voltage of the solar module to the terminal voltage of the battery. From this information, the maximum power that can be output by the solar module into the battery is calculated. The optimized voltage is then selected in order to maximize the current flowing into the battery. A MPPT controller is more complex and expensive than its pulse modulating counterparts. Still the reason that is up for consideration is because it is the most efficient ranging from ninety-four to ninety-eight percent MPPT charge controllers can be used for extracting maximum available power from the power supply unit under certain conditions.
The MMPT control circuit works as a high frequency DC-to-DC converter. They take the DC input from the solar modules and converts it to high frequency AC signal. It then runs the AC signal through a transformer and a rectifier to convert it back to a different DC voltage and current that matches the battery voltage. Since light and temperature conditions vary continuously throughout the day most MMPT charge controllers are now digital microprocessor controlled devices. The devices collect the changing conditions data every thirty to forty-five seconds constantly adapting to the light conditions.

5.2.1.8 Smart Charger Research Conclusions

Due to the complexity and price of both the PWM and MTTP controllers, a simple diversion controller will be designed with the use of a use of an LM317 Adjustable Regulator.

5.2.1.9 Battery Charging Environmental Concern

Every type of battery that was previously discussed should be recycled and or disposed properly after replacement due to their negative impact on the environment. The goal is to develop a battery charging system will be designed that would require the least amount of maintenance and at the same time will prolong the life of the battery that way the need for routine battery replacement would be minimized. In addition if the product ever goes into the market the will be environmental hazard warnings on any non-degradable parts along with instructions of their proper disposal.

5.2.2 Power Distribution

For the power distribution in the feeder system the solar panels are going to be the only input going into battery a solar charge controller will be necessary in order to maximize the amount of power going into the battery. The PCB, motor, camera, and sensors, and communication module (Bluetooth/Wi-Fi). Since the solar panels can only supply energy during the day all the components mentioned would have to run on a low power mode to draw as very little energy as possible. Step down circuit components will be designed to delivers the necessary amount of power to each of the feeder system's components and protect each of the loads. Figure 2 – bellow shoes the power dissipation architecture diagram.

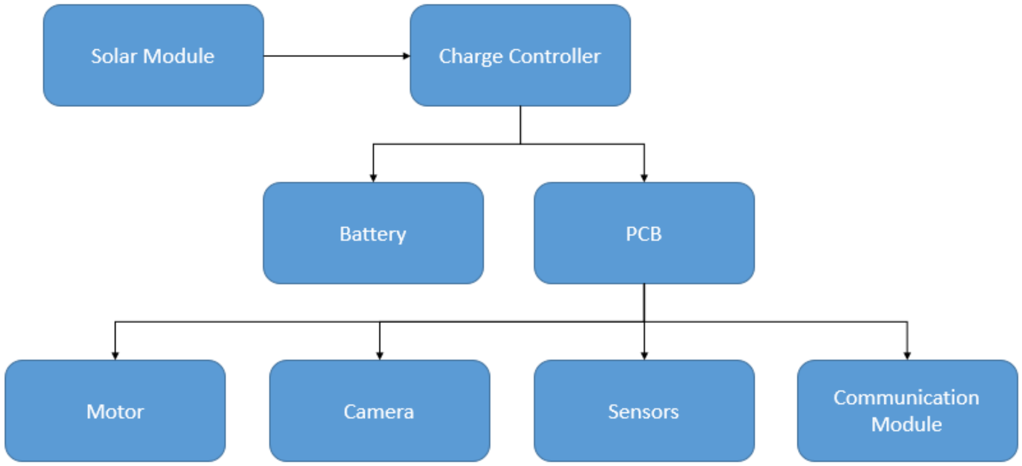


Figure 2 - Power Dissipation Architecture

5.2.3 Solar Panels

As far as the type of solar cells are concerned there is a variety of options available. However, one of the most important factors before choosing is the environmental conditions of where the feeder system is going to be located. Since its purpose id for hunting the feeder is most likely to be set up somewhere in the woods. The amount of solar energy received will be limited from the brush of the trees, also possible changes in weather could also cause the sunlight to be limited. It is for this sole reason that the solar cells used need to be of high efficiency. Another concern is the pricing of said panels and making sure it fits in the projects budget.
The efficiency of solar cells is defined by the ratio of light energy converted into electrical energy. The light spectrum of the received light, the device structure, and material used affect the efficiency of these cells. Most solar cells today are made with silicon because is it the most developed form of making the electronic components. Thus cells that are made with different materials tend to be more expensive.

As it was said before crystal silicon solar cells are the most widely solar cell used today. This technology makes up about ninety percent of the worlds solar cell production. They have high efficiency and can be connected together to increase power output. There are two types of structures available in this category of solar cells which are Monocrystalline and Polycrystalline. As the name implies Monocrystalline is made of a single wafer while Polycrystalline is made of multiple wafer crystals. Another of the photovoltaics technologies that will be considered is the thin film cells.

5.2.3.1 Considerations

The photovoltaic technology chosen will be the one charging the main battery of the game feeder. Therefore it is imperative for the solar panels to be reliable and efficient enough to maintain power for the time range specified on the design specifications of the project. The main factors that will be looked upon while deciding on which technology to go with will be the following:

- Cost
- Efficiency
- Size & shape
- Low light environment capabilities

5.2.3.2 Thin-Film

As the name implies thin film are the thinnest technology of photovoltaics on the market with the thickness of their films varying on the nanometer range. They are made by depositing layers of photovoltaics on a thin and flexible substrate such as plastic. This might be beneficial to when it comes to installing the solar cells on the system. Thanks to their weight and flexibility they can be easily installed around the drum without adding to much weight.
Thin film silicon based technology is the least expensive of all the technologies available. Unfortunately, they also the least efficient. What makes them inefficient is that these cells suffer from the Staebler-Wronski effect which describes the degradation in photoconductivity with prolonged exposure to intense light until they reach a stabilized efficiency from ten to seven percent [A].

Another thin film technology is the cadmium telluride which carry all of the benefits of the previous benefits of silicon without the loss on efficiency. Although these cells yield high efficiencies at a low cost, there are concerns about both the scarcity of tellurium and the toxicity of cadmium makes them an unsuitable option to choose.

5.2.3.3 Monocrystalline

Monocrystalline photovoltaics are the most efficient but also the most expensive on the market. These cells have high efficiency and can be connected together under high transmittance glass to produce reliable, weather resistant photovoltaics. With efficiencies ranging from sixteen to eighteen percent on the standard cells to twenty-five percent on their best research cells they are the best when it comes to efficiency. This high efficiency quality makes monocrystalline the best choice to when in come to charging on a limited light environment. However the Czochralski process which is typically used to grow the crystals and the silicon wafers are cut from cylindrical ingots is an expensive process.

5.2.3.4 Polycrystalline

Polycrystalline, silicon solar cells are more common than monocrystalline cells because they are less expensive. Standard industrial cells yield efficiencies ranging from fifteen to seventeen percent which is slightly less than monocrystalline but this is negligible. They are produced from metallurgical grade silicon by a chemical purification process called Siemens process and the wafers are cut from square ingots. The efficiency of these cells is less than that of monocrystalline cells due to the presence of grain boundaries, which reduces the overall minority carrier lifetime for the material [B]. Figure 3 shows from left to right a thin-film cell that has been deposited on a flexible plastic substrate a monocrystalline solar cell and a polycrystalline cell.

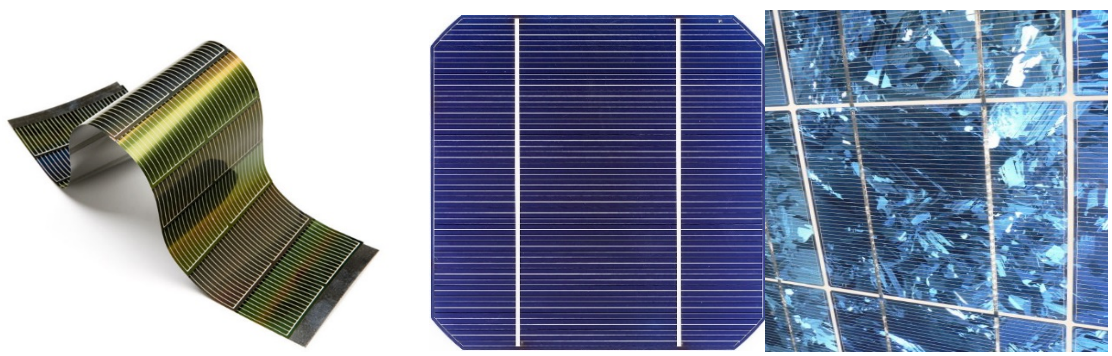


Figure 3 – From left to right a thin-film cell that has been deposited on a flexible plastic substrate a monocrystalline solar cell and a polycrystalline cell. (Permission Requested)

5.2.3.5 Solar Panel conclusion

The most important factor to the group when it comes to selecting a solar cell type is the efficiency since the goal is reaching the most amount of energy produced in order to maintain the game feeder running for days at a time. Therefore, due to the fact that thin film is both inefficient and works poorly on low light conditions it was automatically discarded as an option. After considering the benefits and disadvantages of each crystalline kind, the decision has been made that the extra efficiency and low light capabilities to not be worth the extra expense thus we will go with the monocrystalline photovoltaic technology. Table 5 shows the different types of photovoltaic technologies and their rankings on the four predetermined considerations.

	Cost	Efficiency	Size & Shape	Low Light Conditions
Thin Film	Lowest	Low	Varied &Flexible	Poor
Monocrystalline	Highest	High	Standard	Best
Polycrystalline	Average	Medium	Standard	Good

Table 5 – Different types of photovoltaic technologies and their rankings

5.2.4 Batteries

One of the most important parts on the design is the battery. Due to the fact that the whole game feeder design revolves around having reliable power source the battery chosen in the end will be measured by the following factors:

- Battery Life
- Energy Density
- Ability and complexity to be Recharged
- Self-Discharge rate

5.2.4.1 12V Battery Starting Battery

A twelve volt car battery is designed to provide a very large amount of current for a short period of time. This surge of current is needed to turn the engine over during starting. Once the engine starts, an alternator provides all the power that the car needs, so a car battery may go through its entire life without ever being drained more than twenty percent of its total capacity. Used in this way, a car battery can last a number of years. To achieve a large amount of current, a car battery uses thin plates in order to increase its surface area. However discharging a regular car battery over and over again can ruin it very quickly.

5.2.4.2 Deep Cycle battery

Depending on the demands of all the subsystems in terms of electric current instead of using a regular battery we might have to look into a deep cycle or marine battery. This is because motors tend to draw large amounts of current when compared with the other circuit components those spontaneous yet repetitive large current demand could have an effect on the way the other circuit components behave. They are designed for high discharging rates even as much eighty percent time after time and to provide a steady amount of current over a long period of time. They accomplish this by having thicker plates then regular batteries Deep cycle batteries come in multiple technologies from the most affordable lead-acid to lithium ion and even nickel based.

5.2.4.3 Types

There are multiple available options when it comes to choosing a battery, the main deciding factors when it comes to choosing a battery technology are: size, maintenance, energy density, heat output, cell life, and self-discharge rate.

5.2.4.3.1 Lithium-Ion

The first option that came to mind was the Lithium-Ion (Li-Ion) battery because of their long duration, ability to be rechargeable, and their h. They come in different sizes and with multiple voltage ratings. Li-Ion batteries have a nominal voltage of three point six volts per cell, which is higher than most battery technologies.

Another benefit of Lithium-Ion is that they are memory free. This means that the batteries do not require a complete discharge to avoid crystallization. In addition, their discharge rate is not much higher than lead acid batteries.

Since the feeder system is intended to be left outdoors for days or even weeks at a time. The battery has to be reliable and long-lasting enough for the feeder to continue working with minimal maintenance issues. This can be achieved with a solar charging system meaning that the only requires maintenance would be to replace the battery once every couple of years when it stops holding enough charge. Another thing to consider is the operating temperatures of the batteries in the case of Lithium-Ion batteries the range is in between negative four to negative one hundred forty degrees Fahrenheit, which in within the range of application on the southern and warmer States. Operations of the feeder system on anywhere North of Georgia would not be recommended during winter times.

5.2.4.3.2 Lead Acid

The next choice of battery goes to sealed lead acid. This types of batteries also have the ability to be rechargeable. But when compared to Li-Ion and nickel based batteries, lead acid generally have a lesser voltage density meaning that they are the biggest in size. Their nominal voltage is of two volts per cell which placed them in the middle. However, their self-discharge rate is the lowest of all the types at a five percent per month. In addition, the memory effect does not apply to this type of batteries either. One thing to keep in consideration is that leaving the batteries uncharged or using a too high of a charging voltage will shorten the lifetime of the batteries. This is due to sulfation (left uncharged) and grid corrosion (high charging voltage).

One thing that might present a problem is their maintenance since Sealed Lead-acid batteries have the smallest cycle life of the rechargeable family being considered. Sealed Lead-acid batteries generally have a cycle life of two to three hundred charges if maintained properly. Finally, when it comes to operating temperatures of the lead batteries the range is in between negative four to negative one hundred forty degrees Fahrenheit.

5.2.4.3.3 Nickel Based

Finally, there are the nickel-cadmium and nickel-metal hydride. When compared to lithium Ion nickel based batteries have a lower energy density and a higher self-discharge. Also both of this batteries tend to come in larger sizes with a nominal voltage of one and a quart volt. However, nickel metal batteries tend to have triple the capacity of nickel-cadmium meaning out of the two nickel metal is the most likely to be chosen of the two. Both nickel based batteries require minimal maintenance by only needing to be replaced every couple of years and are capable of being recharged.

When it comes to the memory effect nickel-cadmium need to be fully discharged occasionally to avoid internal crystallization that will diminish the capacity of the batteries. Nickel-metal however do not suffer from this effect which makes them more likely to be chosen out of the two. Another negative factor when it comes to these batteries is that when compared to lithium ion their self-discharge is higher sitting at a twenty to thirty percent per month. This will have to be considered when figuring out how the charging rate of this batteries.

5.2.4.4 Battery conclusion

Comparing all of the possible rechargeable battery technologies Lithium Ion and the nickel based batteries have the most desirable traits. Both nickel based batteries have low charge times however, nickel cadmium has the longest cycle life of them all. On the other hand, at the exchange of some of this battery life nickel metal has more energy density making it more balance than its cadmium counterpart. Now moving into Lithium Ion batteries have the highest nominal voltage and energy density a long with the second lowest self-discharge rate and charging times. After organizing their characteristics on the table below it makes the most sense that the battery for this design to be lithium Ion type, however due to economic constraints and the budgeting of the project it will most likely a deep cycle lead-acid battery. The reason being that although it is it not the most reliable of them all, it has a relatively simple charging algorithms and by using a deep cycle it will be a reliable and long lasting of all other battery technologies. Table 6 bellow shows each battery types characteristics in a much more organized manner.

	Lithium ion	Lead-acid	Nickel-cadmium	Nickel-metal-hydride
Cycle Life	1000	300-500 w/ full discharge	1200-1500	300-500
Charge Time	1 hr. or less	8-12 hrs.	1 hr.	1-1.5 hrs.
Nominal Voltage	3.6V	2V	1.25V	1.25V
Overcharge Tolerance	low	high	moderate	low
Energy Density (Wh/kg)	90-190	30-50	60-120	45-180
Self-Discharge per month	10%	5%	20%	10%

Table 6 – Battery characteristics

5.4 Weather Sensors

To improve the data gathered for scouting, the pictures will include a date/time, humidity, barometric pressure and temperature text file. It was found that in the case of deer hunting after analyzing the barometric pressure and the deer observed, there were certain feeding and behavioral patterns seen in the number, size and sex of the deer correlated to the barometric pressure. There is also statistics published for hunters informing them of ideal temperatures and humidity as well as time of day for the optimal animal activity. The GFC will carry all of these sensors to allow specific and thorough analysis of the area being hunted rather than generalized information.

5.4.1 Temperature

Thermocouple: A thermocouple measures the change in voltage between two dissimilar joined metals to indicate the temperature. Depending on the type of thermocouple, this method has a wide operating from negative two hundred to two thousand degrees Celsius while the accuracy is less than one degree Celsius. The type refers to the material they are made of, for example a type J thermocouple is made of Iron (+) and Constantan (-) and can measure a range of temperatures from negative forty to seven hundred sixty degrees Celsius. Other advantages are the sensor is self-powered, requiring no outside power supply, inexpensive, and rugged enough to survive harsh environment. The main

drawback is the voltage signals produced are in the microvolts so noise and drift become a factor.
Resistance temperature detector (RTD): The RTD measures the difference in resistance due to the change in temperature. The temperature measuring range is negative two hundred seventy to eight hundred fifty degrees Celsius depending on construction material and requires an external stimulus to function. Accuracy and stability rate among the highest of the temperature measuring devices with an accuracy of zero point zero three degree Celsius. The main flaw of the RTD is self-heating due to the external stimulus which usually is a current source. The heating requires an error formula to correct or an alternate method of wiring using four wires, this sensor type also runs higher in price.

Thermistor: A thermistor works on the same concept as the RTD measuring a change in resistance reading temperature ranging from negative one hundred to three hundred degrees Celsius. Accuracy is about zero point one degree Celsius but because the sensor is less linear than that of the RTD a correlation factor equation is needed. Requiring a two wire design makes the thermistor easy to setup and operate. Thermistors also have a fast response time because of their small stature. The down side is they are not as rugged as the thermocouple, have a more limited temperature range, have the same heating problems as the RTD and because they are a semiconductor, experience de-calibration issues at high temperatures.

Silicon Diode: The silicon diode temperature sensor requires a simple circuit to implement and yields an accuracy of plus or minus two degrees Celsius from negative forty to one hundred fifty degrees Celsius using the TO-92 package. The circuit has to provide offset, excitation and amplification, which can be done with the setup shown below in Figure 4 - Silicon Diode Circuit. The Burr-Brown REF200 is a dual one hundred micro amp current source/sink that will provide the excitation and offset. The OPA1013 is an op-amp for five volt applications which provides the amplification needed.

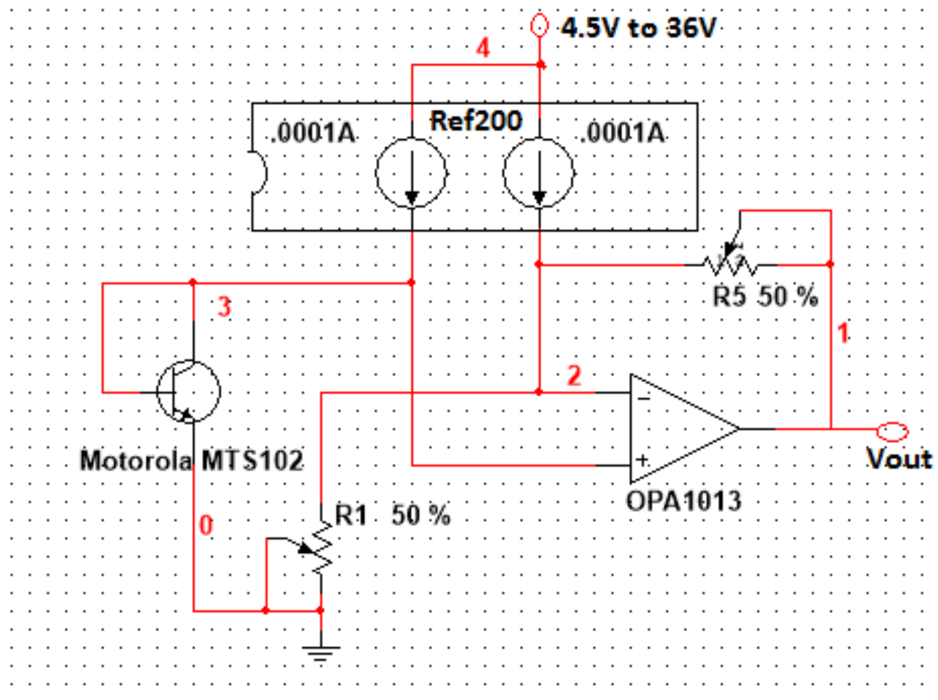


Figure 4 – Silicon Diode Circuit

5.4.2 Humidity

Humidity is the amount of water vapor in the atmosphere. The three most commonly used humidity measurements are Relative Humidity (RH), Dew/Frost point and parts per million. Relative humidity is the ratio of the quantity of air moisture content to the maximum quantity of moisture that the air can hold at the given temperature and pressure in air multiplied by one hundred to give the percentage. The percent of RH can also be found by taking the ratio of the absolute humidity and saturation humidity and multiplying by one hundred. Because the RH measurement is most commonly used in the weather forecast the GFC will utilize a senor to produce an RH readout. Of the RH sensors available the focus was on two main types of electronic polymeric humidity sensors, a resistive type and conductive type.

Resistive type: As per the name, the resistive RH sensor measures the change in impedance of a substance able to attract and hold water molecules such as a conductive polymer, salt or treated substrate. The measured impedance is nearly an inverse exponential to RH. The accuracy range typically is one to ten percent depending on materials used in the sensor while the rise time varies from two to five minutes. The long term stability is less on this sensor losing accuracy per year of around plus or minus three percent.

Capacitive type: The capacitive RH sensor is made of a substrate of glass, ceramic or silicon with a thin film of polymer or metal oxide between two conductive electrodes. The change in dielectric constant is measured in the sensor and is nearly proportionate to the RH. The advantages of the capacitive sensor are its ability to function in high temperatures and operate in a moist environment. The rise time is fifteen to ninety seconds and the accuracy ranges from one to five percent. Long term stability is low at around one percent plus or minus per year.

5.4.3 Barometric Pressure

Atmospheric pressure is measured by a barometer which is why it is known as barometric pressure. The atmospheric pressure is dependent upon the altitude above sea level because pressure varies depending on the amount of air above the point being measured and due to weather patterns. This requires the typical barometric pressure sensor to also measure altitude so the GFC will have the option to display this information as well. The focus will be on electromechanical pressure sensors which take an applied pressure and convert it into a readable electrical signal. There are four types analyzed: piezo-resistive integrated semiconductor, potentiometric pressure sensors, capacitive and flow sensor.

Piezo-resistive Integrated Semiconductor: This design utilizes a transducer that coverts stress into electric potential and electric potential to stress. It only detects an output when there is a change in input making it only useful for changing pressure readings. It is also sensitive to electronic interference so special care must be taken in placement and protection of the sensor.

Potentiometric Pressure Sensors: These sensors use a capsule, bellow or Bourdon tube that react to pressure and move the wiper on the potentiometer. It is a low cost alternative but sacrifices repeatability and hysteresis due the need for the wiper to maintain sufficient force on the element.

Capacitive: Capacitive sensors consist of a thin plate on one side of the capacitor that when exposed to pressure changes the capacitance. Then the frequency is interpreted to determine pressure but results may be skewed if the dielectric constant isn’t maintained level. These devices are usually larger to produce a useable signal to determine pressure.

Flow Sensor: Flow sensors have the ability to measure low-pressure flow across their sensing element. The sensing element is a silicon integrated circuit with a thin film thermally isolated structure bridging over a cavity located within. Because this sensor requires airflow, it would need to be installed on the outside of the housing but it has a small footprint and a fast response.

5.4.4 Integrated Combination Circuits for Sensors

Due to the fact the GFC needs humidity, barometric pressure and temperature measurements, it could use the SparkFun weather shield to connect all of the sensors. This shield is a direct plugin for the Arduino Uno and can be modified for the Arduino Mega2560. The weather shield has extra options available to expand future sensors to include wind and rain accumulation. This shield utilizes the HTU21D humidity, MPL3115A2 barometric pressure and ALS-PT19 light sensors with open source Arduino libraries. This shield also contains the voltage regulators for each sensor and operates from three point three to sixteen volts making it a direct connect to the Arduino Uno circuit. The MPL3115A2 barometric sensor combines pressure, altitude and temperature readings while the HTU21D humidity sensor provides humidity and temperature. The shield itself costs forty two dollars and seventy five cents while the other potential candidate stand-alone sensors cost twenty six dollars and sixty five cents.

5.5 Camera System

5.5.1 Motion Sensor

The motion sensors in the GFC will be responsible to trigger the camera system to capture what caused movement within the vicinity of the feeder. There are two basic types of sensors: active, which emits energy to pick up movement and passive, which does not emit energy but reads changes in existing energy in the area selected.

Passive Infrared (PIR): Passive infrared sensors detect widespread change in heat across its field of view or with rapidly changing energy levels, the sensor will trip. These sensors offer a wide detection range and typically consist of two slots in which IR sensitive material is placed. These two slots provide the comparison of IR readings to detect equal reading and does nothing or different readings trigger.

MicroWave (MW): Using the Doppler Effect for analysis, this sensor emits microwaves and detects movement by the change in frequency caused by the reflection off of an object (in this case, an animal). The design will withstand harsh environments and sense movement through boundaries such as brush. Although the detection through brush would be a beneficial feature, the sensor works in intervals, leaving gaps in sensing, need constant power requiring a large battery, and are known to be problematic having false triggers.

Area Reflective: The area reflective emits infrared and measures the time it takes to return after reflecting back in projected area. When movement of an object shortens this time, the sensor is triggered. Because the area reflective depends on objects moving into the field of view to refract the IR ray at a shorter time, this may cause false triggers in densely wooded feeder placement due to swaying trees and/or brush.

Ultrasonic: Ultrasonic sensors works by sending ultrasonic sounds out and determining the length of time to return. If an object move in the line of the wave it will be altered and trigger the sensor. The analysis uses the Doppler Effect frequency to detect the changes in echo and amplitude. There are also passive ultrasonic sensors which listens for sounds. The disadvantage being that the senor will be in the outdoors where it may falsely trigger due to background noise.

5.5.2 Cameras

The design of the Game Feeder uses the camera to serve one primary function, which is to allow the hunter to view feeding patterns of wildlife by taking pictures whenever the motion sensors detect any nearby activity.

5.5.2.1 Weatherproof TTL Serial JPEG

The first option of cameras that we will discuss is the Weatherproof TTL Serial JPEG Camera. The main benefit of this camera is that is already built with a metal case that makes it weather proof. In addition, it also has an IR LED system for night photos. Since these cameras are designed for security purposes, they suit the purpose of taking clear pictures when movement is involved very well. The camera comes with TTL serial link that is able to transmit videos and pictures. It can also snap pictures at 640x480, 320x240, or 160x120 and pre-compress them to JPEG images. This makes them highly convenient to store on an SD card. It has a maximum operating voltage of five volts DC.

The Weatherproof TTL is equipped with multiple extra features. For example, it has manually adjustable focus, auto-white-balance, auto-brightness and auto-contrast, as well as motion detection built in with a maximum monitoring distance of fifteen meters. Another benefit of this type of camera is that using the module is pretty simple and only requires two digital pins (or a TTL serial port). By default this serial camera transmits at a thirty-eight thousand four hundred baud rate. This camera module is also compatible with Arduino boards. One setback of this camera is that the viewing angle is sixty degrees, meaning we would have to install six of them for a full three hundred and sixty view of the feeder surroundings. Writing code that is effective on all six cameras could also prove to be a challenge later on. Also, with each camera going for about sixty dollars, the total cost would be around three hundred dollars.

5.5.2.2 360fly Panoramic 360° HD Video Camera

The next camera choice is the 360 Fly. As the name implies, it is a camera that can take full three hundred and sixty degree panoramic pictures. This camera includes many technologies like Bluetooth, Wi-Fi, and water and dust resistance. With these capabilities, the 360 Fly can be linked directly to the mobile application without having to create an extra module on the circuit board, which could simplify connectivity. The 360 Fly is available to be purchased online for three hundred and ninety-nine dollars.

Unlike the weather proof TTL, the 360 Fly does not include motion monitoring sensors. Therefore, the motion sensors would have to be purchased and installed separately. In addition, we do not know how compatible this camera model would be with an Arduino board and that could prove a challenge when writing code.

5.5.2.3 GoPro Spherical Solutions

Finally, there are the GoPro Spherical Solutions. Simply put, the Spherical Solutions is a GoPro stand that hooks up to six GoPro Hero 4 cameras in an arrangement that lets them capture video in all directions simultaneously. The relevant technical specs of a GoPro Hero include Bluetooth and Wi-Fi connectivity, photo resolution of 12MP, night photos, and a rechargeable lithium-ion battery. Similar to the 360fly, the GoPro Hero does not have a built in motion sensor. GoPros are designed for people that participate extreme sports. Having this in mind, their camera designs are made to be weather proof. The one thing that makes this camera infeasible for implementation would be cost. Being a popular brand named product, the price of these cameras together with their stand is about three thousand dollars.

5.5.2.4 Camera conclusions

After carefully considering the camera options, we have decided to use the Weatherproof TTL Serial JPEG Camera for the feeder design. However, in order to keep the design cost effective, the camera system will be integrated a little different than it was originally intended. The new alternate camera system will not have six cameras simultaneously covering a space of three hundred and sixty degrees. Instead, it will be a single camera mounted on a servo motor. The environment surrounding the game feeder will be divided into four quadrants. Then there will be four PIR motion sensors installed around the game feeder, each of which will detect motion in their respective quadrant. After motion activity has been detected, the microcontroller will determine which quadrant it is coming from and point the camera in that direction by rotating the servo into the quadrant. This system, although it might be more complicated to implement than the previously discussed ones, is not impossible to construct. In addition, it turns out to be considerably less expensive than the other three camera systems, which is much more beneficial.

5.5.3 Camera Flash System

Depending on the camera choice, a light sensor might be required as well as some form of light emitting diode (LED) flash. The way the system works is that the light sensor detects if the brightness of the surrounding environment, measured in LUX, is bright enough to take a picture without flash or if flash is required.

5.5.3.1 Light Sensors

There are many light sensors available on the market, but the three main types utilized are photo-resistors, photodiodes, and phototransistors.

Photo-resistor: A photo-resistor is made of a high resistance semiconductor material. The photo-resistor is a variable resistor that decreases resistivity as LUX increases. This occurs due to photons being absorbed by the semiconductor, which, in turn, gives electrons enough energy to jump to the conduction band. The result is electricity being conducted by these free electrons, which reduces the resistance. There is a large range of resistances and sensitivities offered in this product line with a relatively inexpensive cost.

Photodiode: A photo diode is a device that turns lights into currents. Current is generated when photons are absorbed by the photo diode. They have a slower response time as their surface area increases. The can contain photo filters in other to receive a particular wavelength a solar cell is technically a bunch of photo diodes connected in series together to create a considerable amount of current.

Phototransistor: A photo transistor is simple put a bipolar junction transistor that uses a photodiode at the base connector. Their application is to function as on or off switches depending of the lighting condition. In this case they can be implemented as a control system for the camera flash. For instance on an algorithm on which whenever the transistor is not getting light and the camera becomes active from the PIR sensors to also make sure to activate the LED flash system.

5.5.3.2 Light emitting diodes

The two types of LEDs used for game camera flash are white LEDs or IR LEDs. A flash control circuit is required to turn on the LED and the light sensor would set the flash control circuit to on or off through the MCU.

White LED: Light emitting diodes is a two lead semiconductor light source. It works as a PN junction diode that generates light whenever activates. The activation voltage depends on the physical characteristics of the diode. Similar to photodiodes their activation voltage is depends proportionally to the surface area. LED in essence are the reverse of a photodiode. Their application is to serve as a more efficient and low energy light source. However, shining a bright led to the game while its feeding could have negative implications by scaring away the animals.

IR LED: An infrared LED is also a semiconductor light source. In essence, is it operates the same as a regular white or colored LED with the exception of it emitting light on infrared wavelengths. This characteristic is more applicable for the feeder system design because although some wild live can maybe sense infrared wavelengths they are not as aggressive as light from the visible light spectrum in the middle of the night.

5.5.4 Servo Motor

In order to control the camera positioning, a servo moto will be used to rotate the camera to the different quadrants that will be established by the positioning of motion sensors. Once a sensor detects motion, it will send a signal to the MCU, which will determine the quadrant from which the motion disturbance happened. After this, the servo motor will rotate accordingly in order to position the camera on the correct quadrant before taking a picture.

This is possible because servo mechanisms function as closed loop control systems. Unlike a regular DC motor, which spins continuously with a direction depending on a variable signal, a servo motor compares the input signals to its current output signal, creating the feedback signal that determines if and how much the servo mechanisms will rotate. Once the input matches the output signal, the feedback signal is no longer generated and the servo stops moving. In following sections we will discuss the different types of motor choices and determine which one is the best option.

5.5.4.1 Brushed Servo

Brushed motors are simple electric motors that use metallic brushes to deliver current through the coil windings. The electromagnetic force of the windings and a permanent magnet make the motor spin. Because of this, a brushed motor can be powered by DC current, making it easier to implement into the system. A problem that the brushed motor presents is that continuous use of the same brushes wear these brushes down over time, casing friction that reduces the amount of torque and efficiency of the motor, along with generating extra noise and heat. To avoid this effect, maintenance is required to replace worn motor brushes.

5.5.4.2 Brushless Servo motor

On the other hand, brushless motors, as it is implied in the name, do not use bushes to deliver current. Instead they use an external permanent magnet rotor and a set of coils that use their electromagnetic fields to spin the rotor. Since the rotor is never in contact with any brushes, servo motors are more efficient, can reach a higher speed rate, and produce less heat and noise than brushed motors. All these benefits do come at a cost, since their design are more innovative so are their controls. In addition, these controls are required to run the servo motors, so we would be looking at a double the price if we choose to go with a brushless motor. Another thing to keep in mind is that most of brushless motors rely on AC current to operate but the game feeder runs on DC therefore to implement one into the power system we would need to add an inverter.

5.5.4.3 Continuous VS Limited motion

Another factor to be concerned with in servo motors is the degrees of rotation. A common servo motor only rotates from zero to one hundred and eighty degrees. This presents a problem because we only have one camera, which would limit the field of sight to only two quadrants. This is why we would need to modify the regular servo to give it more degrees of rotation. Luckily, Adafruit sells a brushed continuous rotation servo for eleven dollars and ninety-five cents. This type of motor has already been modified to move in a full three hundred and sixty degrees by using a pulse with modulation.

5.5.4.4 Stepper Motor alternative

A stepper motor is a good alternative for the camera motion device. A stepper motor is a brushless synchronous motor that uses digital pulses as instructions to perform a digital step rotation. Each digital pulse is assigned to an individual step and the amount of steps vary from motor to motor, but they can facilitate much more than are needed for the feeder system implementation. Some of the benefits of steppers are that steppers are much simpler to maintain than servos. They are less expensive, especially in small motor applications. They don't lose steps or require encoders if operated within their design limits. Also, steppers are stable at rest and hold their position without any fluctuation. However, without an encoder, steppers will run on an open circuit mode that creates heat on the motor.

5.5.4.5 Motor Conclusion

Putting everything into consideration, choosing a motor is a pretty tough call. All of the choices have pretty balanced when it comes to pros and cons. Brushless servos are considerably more efficient than brushed, however there is the problem with adding an inverter just for it and if it is worth the extra efficiency and speed. The alternative option of a stepper motor is also enticing but without an encoder the overheating could cause a problem since we cannot predict how often the camera will operate and overheating of components could cause a serious environmental hazard. Thus, in conclusion the best possible path to go is with the DC brushed continuous servo motor that Adafruit offers. Not only does this motor fit all of the required criteria, but it is also compatible with Arduino software environments which is the one that is going to be implemented in the feeder system. Making it a perfect fit, the slightly less efficiency is something we will have to deal with.

5.6 Software

The Game Feeder Cam system also includes many features that are controlled by software. The GFC design that was achieved is customizable by the user. Many software features were added to the system to make this a unique product. Some of these features include:

- Custom feeding schedules.
- Picture Gallery
- Instant Picture
- Changing Motor Speeds

These and many other features will be discussed in the Software Design section of this paper. These software features are achieved through the communication from the hardware. For implementation, these custom settings are able to be changed and modified through an easy to use interface for the end user. This goal can be achieved in many different ways. Considerations include a mobile Android or iOS application, or a web application that can be accessed through any browser. These considerations have their pros and cons and these will be discussed below. For each consideration mentioned the required software and implementation will be discussed.

5.6.1 Android Application

Android is a mobile Operating System based on the Linux kernel. It is currently being developed by Google, It is the most popular mobile OS. It is mostly used for touch screen applications such as smartphones and tablets. The latest version of Android is Android 6.0 Marshmallow. The Android Operating System is one of the considerations that is being taken into consideration. The application can be installed on any device running Android. Android is being used in more than 190 countries around the world. Android applications are package in the Android Package Kit (APK) format. This is a type of archived file format that is used in the extraction and installation process of an Android application. The Android application would cover the bases required for the settings and features the team would like implemented for the software aspect of the product.

5.6.1.1 Java

The official language of the Android Operating System is Java. Many Android parts are written in Java and its API are designed to be called by Java. Java is the official language for Android development. Other languages such as C and C++ can be used to write Android applications. This can be achieved by developers if they use the Android Native Development Kit (NDK). This form of application development is not promoted by Google; it claims that most apps will not benefit from the NDK.

Java is a programming language that was first released by Sun Microsystems in nineteen ninety-five. Many applications and websites run Java. Java can be found in many modern devices today. Some of these include, laptops, datacenters, game consoles, and mobile platforms. Java does not compile to native machine code otherwise called (native processor code), it relies on a “virtual machine’ that understands the compiled code called Java bytecode. Bytecode is a set of instructions that are similar to the machine code found in CPUs. Every platform that runs Java will have the Java Virtual Machine (JVM). The original virtual machine that ran on Android is called Dalvik. The next generation of the virtual machine is called Android Runtime (ART). Many technologies are used to to speed up the processes of execution. Just in time compilation (JIT) and Ahead of time compilation (ADT) are some of the technologies.

5.6.1.2 IDE

Since Android applications are usually written in Java, any text editor could be used to write the code for an application. The easiest way to program and debug Android applications is using the integrated development environment (IDE) Android Studio. Android Studio is based on IntelliJ IDEA. IntelliJ is an IDE that can be used to write and debug Java applications. Android Studio offer many additional tools and features to simplify Android apps development. It includes code templates, tools to find compatibility and performance specifications, and APK file generations. Using Android Studio will give the developer many tools to test and emulate their application on a running Android platform. This is all done through the Android SDK which is discussed below.

5.6.1.3 Android SDK

The Android Software Development Kit (SDK) is a set of tools that are used to develop Android Applications. The Android SDK includes many features such as, required libraries, an emulator, the application program interface (API) for Android, and many more. These development tools are available in many platforms including, Windows, Mac, and Linux operating systems. Each new version of the Android OS that Google releases requires that the SDK is released, this way developers can start developing apps for the current operating system. Android Studio combined with the SDK are the necessary tools needed to develop a working application that can be Game Feeder Cam project.

5.6.2 Apple iOS Application

The second consideration for this project would be developing an iOS application. iOS was originally named iPhone OS. The iOS mobile OS is developed and maintained by Apple. It is the second most popular mobile OS in the market. iOS is used to power many Apple products including the iPhone, iPad, and iPod Touch. The latest version of iOS is iOS 9 (9.3). iOS uses the file format of IPA which stands for iPhone Application Archive, this is the executable file format that iOS uses for the extraction and installation of applications. iOS is also a good platform to build the GFC application on.

Development on the iOS operating system has to meet certain criteria. Unlike with Android, iOS development can be more difficult due to iOS not being such an open source OS as Android. To distribute an iOS application a developer or organization is required to pay a yearly license. Also iOS uses different programming languages to code and develop its applications. The programming languages used are Objective-C and Swift, we will discuss these further in the section blow. Finally, developing for iOS and the setup is easy if developing in a Mac OS X environment. Windows and Linux users can find themselves with some difficulty when trying to develop outside of the Mac desktop environment.

5.6.2.1 Swift and Objective-C

The two main programming languages used for iOS application development are Swift and Objective-C. These two programming languages will be discussed in this section.

First let’s discuss Objective -C. The primary languages for writing and developing applications for iOS is Objective-C. It is based on the C programming language with additional features. It provides object-oriented features and a dynamic routine. It inherits many aspects of C including, its syntax, primitive types, and flow control statements. Additionally, it adds syntax for defining classes and methods. It also adds language level support for object graph management and object literals. Many responsibilities are not done until runtime, it uses dynamic typing and binding. Since Objective-C adopted many object-oriented aspects during much of the development process most time will be spent working with objects. Objects are instances of classes. Classes will be written by the developers and some are already provided by libraries. A newer programming language is now being used to develop iOS applications. The new programming language is called Swift.

Swift is a new programming language used to build apps, it is based on the best aspects of the C programming language and Objective-C, without the constrains of C. Swift was made to adopt safe programming patterns and adds new modern features for programmers. It supports the popular Cocoa and Cocoa Touch frameworks. The Cocoa and Cocoa Touch are the application development environment for applications in OS X and iOS, respectively. Both include the Objective-C runtime and two core frameworks. Cocoa refers to the Foundation and Appkit frameworks that are used for developing OS X applications. Cocoa Touch includes the UIKit framework it is used to develop application for iOS. This features help integrate existing Objective-C code into new more modern Swift code.

5.6.2.2 IDE

The official integrated development environment (IDE) used to develop Apple applications is called Xcode. It is used to develop applications for OS X and iOS environments. It was first released in two thousand three, the latest stable version is seven point three. The IDE is available free of charge through the Mac App store. Many programming languages are supported by Xcode, for example C/C++, Objective-C, Java, Python, Ruby, and Swift. There are many executables that can be compiled with Xcode. Architectures such as Intel x86 (thirty-two and sixty-four bit architectures), PowerPC, and using the iOS SDK it can compile for the ARM processors. For application design, it also includes an interface builder that can be used to shape applications with ease. With the vast libraries of features made available by Apple to develop and implement applications, the Game Feeder Cam mobile application can also be developed and made available to iOS users. The iOS market is a very specific one, but it is also very competitive alongside Android. This way iOS device owners can also enjoy the GFC custom functionality.

5.6.3 Web application

Finally, a web application is the final consideration for implementing the custom features we would like for the Game Feeder Cam. A web application is versatile; it can be used on any modern operating system that has an internet browser.

This means that many devices such as, desktops, laptops, smartphones, and tablets could access and use the web application. This final consideration has its pros and cons just like the others and many of these will be discussed in the following sections.

The idea of putting all the custom features into a web application is for the reliability of connectivity from anywhere there is an internet connection. Many things are required for this to be a fully implemented idea. First to run a website, a web server is needed to translate all the code and resolved it for the browser to display it. This would require running a web server on the Adruino Mega2560 microcontroller. The next thing to implement is connectivity. For the web application to be active it requires an always on internet connection. This can be accomplished by integrating a GSM (3G, 4G, or LTE) module into the microcontroller. This would provide the web server an IP addressed that can be remotely accessed from anywhere on the internet.

The advantages of going with this idea is remote connectivity. Being able to set and control the many custom features that will be implemented into the GFC from anywhere as long as you have an internet connection. Also you are not limited to one single device, any device running a modern web browser can be used to access the interface. With these pros also come many disadvantages.

This idea will prove to be expensive in regards to performance and price. Since an always on internet connection is needed a monthly data plan would be required for the always on capabilities. This will also reduce battery life and increase power consumptions. This is because of the internet connection and the running web server. Many microcontrollers are very energy efficient, but this idea would still cost more to implement. Many different tools and programming languages can be used to accomplish this task.

5.6.3.1 Web Programming Languages

Many programming languages are used to accomplish the task that a web application would require. HTML and CSS can be used for the front-end look and feel of the application. Python and JavaScript are used for the back-end programming. Many microcontrollers support the use of Python for controller the interface. The combination of the languages mentioned would be the result of implementing the custom features through a web application. Many other programming languages could be used, but during the research of this paper it was found that the ones that have been mentioned are the most popular. Also they would be capable of accomplishing the task required for Game Feeder Cam.

5.6.3.2 IDE

Since many programming languages would be used many integrated development environments can be used. All of the code can be written in a text editor of the developer's preference. There is are many IDEs that will combine most or all of the programming languages mentioned. For example, the NetBeans IDE provides support for HTML/CSS/JavaScript and Python. Using one single IDE could prove to be good in the long run since the developer would not have to get used to different environments for each language they plan on using.

5.8 Feeding system

The feeding system consists of the motor, motor control, feed disc and feed funnel. At the programmed time the motor will turn on via the MCU and feed will disperse outward in three hundred sixty degrees.

5.8.1 Motor

The GFC will need a DC motor to spin the feed distribution plate. Of the many variations of DC motors the two types of DC motors being considered are a brushed commutator and brushless commutator. The DC motors being looked at are either six or twelve volts. Lastly the motor will need threaded bolt holes in the top to mount inside the feeder housing, keeping the main motor out of the environmental elements. All that will be exposed is the motor shaft to affix the feed distribution plate via a set screw on the shaft recessed notch. The recessed notch on the shaft measures approximately one quarter inch to adjust the plate height allowing an increase or decrease in the amount of feed sitting on the plate.

Brushed Motors: A brushed motor uses contact brushes that connect to the commutator in order to reverse the direction of the current two times per cycle. This allows current flow through the armature for the electromagnetic poles to push and pull against the permanent magnets outside of the motor. When the polarity switches it enables inertia to keep the motor turning in the prescribed direction. The brushed motor is simple and inexpensive to control, requiring a two wire control. Due to the lack of electronics, it is able to operate in extreme environments and has a low cost of construction. Some disadvantages to the brushed motor are brush arching which generates noise causing EMI, poor heat dissipation, periodic failure due to brushes wearing out, and a low range of speed. The noise generated by the brushed motor can cause interference with the microcontroller circuit. To reduce the possible problems caused by the noise three, zero point one microfarad capacitors can be soldered onto the motor. One capacitor is soldered between the motor terminals and one soldered from each terminal to the motor casing.

Brushless: Brushless commutation motors use a permanent magnet external rotor. The motor uses back EMF in the motor oils themselves or Hall Effect devices to detect rotor position and the drive electronics to control the rotational speed. The Hall Effect sensors provide the signal to the drive electronics to activate the coils acting as a three-phase synchronous motor. These motors excel in efficiency because there is no drop in voltage across the brushes making their output power to size ratio better than that of brushed motors. Brushless motors also have reduced electric noise, better heat dissipation and a higher speed range. The drawbacks to using brushless commutation are the complexity of the electronics and controls which results in the increased cost to construct and control. The electronic complexity also limits the type of environment the motor can operate and the housings required.

5.8.1.1 Motor Controller

The housing purchased for the project came with a brushed motor. As such, a brushed motor controller is required. There are two motor controller methods that are being considered simple circuit from the microcontroller or a breakout motor control module.

Brushed Motor Circuit: Because the motor for the GFC is only required to rotate in one direction, a simple transistor circuit in combination with a microcontroller that provides a pulse width modulation (PWM) analog output pin. This design will require a six volt DC motor, PN2222 transistor, 1N4001 diode, and a two hundred seventy ohm resistor. Using the Arduino Uno R3 board as an example, pin D3 for analog out PWM is connected to the resistor to limit the current into the transistor base. The diode is connected parallel to the motor to prevent damage to the transistor due to reverse current from the motor. In this particular example, the PWM duty cycle can be adjusted from zero to two hundred fifty five, which is the highest duty cycle resulting in top speed.

Motor Shield: Adafruit has an available motor shield model V2 for powering up to four DC motors or two stepper motors. Although this may be excessive for the GFC, it allows for expansion in the future if the servo controlled feed door was to be implemented. The V2 uses a TB6612 MOSFET driver to produce an output of up to one point two amps continuous and three amps peak from four point five to thirteen point five volts for a brushed DC motor. This shield eliminates the need to program the PWM with the use of a dedicated PWM driver chip and uses only two shared I2C pins for control. Depending on the amperage, the purchased motor draws an additional heat sink may be required after one point two amps on the driver motor to prevent thermal failure. The amperage draw shouldn’t be a problem for the GFC since the motor will run three, six or nine seconds twice a day which would qualify as peak draw rather than continuous. Speed variation is adjustable in one half percent increments and because of the built in PWM the transition is very smooth.

5.8.2 Feed System Housing

The feed system housing on most feeders on the market of similar design to the GFC hold the motor with feed dispersion disc as well as electronics and power source. The motor shaft and disc are external while the rest of the system is enclosed in the housing. By analyzing current designs, it has been proposed to make a CAD drawing and have one produced at the three dimensional printing lab.

5.8.3 Feed Distribution

While looking up feed distribution methods it was found that there are many methods used on the market. The two basic methods are gravity and mechanical and refer to how the feed is fed from the container and how it is dispersed from the point it leaves the container.

Pure Gravity Fed: After researching this method of distribution, it was discovered that although it is the easiest and most cost effective to implement, it will use much more feed then a mechanical system. The gravity fed system uses only gravity to let feed onto the ground assuming the feeder is on the ground and only stopping the flow of feed when the corn flowing out piles up to block the hole. Another variant of this system is the elevated gravity fed system which allows the corn to flow into a trough system and when full, the flow stops. The drawback to this system is the amount of corn used depends on how much the game is willing to eat on a given day. Also the corn will be allowed to sit in the elements which could lead to moisture souring the feed, mold and insect infestation.

Combination: The combination feed distribution system consists of a mechanical and gravity feature. Most use gravity to allow the feed to accumulate on a feed disc mounted to a motor. The feed fills the disc to capacity and stops until the motor is activated at a preprogrammed time at which the motor will spin using centrifugal force to disperse the corn away from the feed system and allowing a constant flow of corn to fall. When the motor stops the corn fills the disc to capacity once more before stopping, queuing for the next feed time. The distance the corn is spun away from the feeder is proportional to the speed selected by the user and the amount of corn distributed is attributed to the duration the motor is turned on, also controlled by the user. Another version of this is gravity fed to a mechanical door which, when open, becomes a trough or when open empties into a trough. These feeders are game dependent and primarily target deer as they are tall enough to reach the troughs. This makes this method less useful to the sportsmen who target a variety of animals such as squirrel, deer, hog and turkey. Another drawback is that the feed could be exposed to moisture as discussed above in the pure gravity fed section. For these reasons, further research will be done on the components needed for a combination system consisting of either a gravity funnel to disc system or mechanical to disc system.

Feed Distribution Disc: The feed distribution discs found on the market are constructed of metal containing an indentation for feed to fall to before centrifugal force causes the feed to move outward before hitting metal fins placed on the outside of the disc. The fins throw the corn outward away from the feeder in order to keep game from getting close to the feeding apparatus. Also proposed was to create this disc of plastic via a CAD drawing of existing products and three dimensional printing.
Mechanical feed door: The mechanical feed door would be a design that would mitigate the concern for food infestation or spoiling but requires complicated mechanical system. Some use worm gears and a motor to open and close a door while others use a servo attached to the door rotating open and close. A drawback to this system is that if there is a malfunction, depending on the design, the feed could be allowed to flow freely out, causing a loss of up to three hundred fifty pounds of corn feed.

5.9 Communications

The Game Feeder Cam uses wireless communications for easy to use interaction and remote notifications from the system. The communications system of the GFC has been decided to use Bluetooth and a GSM module for the final implementation. Both of these technologies prove to be useful for the final product. The decision was made by comparing with other wireless technologies. Some of the technologies research for the project are discussed below. In the Communication implementation section of the paper it is discussed how the chosen technologies were implemented and their functionality. Finally, the technologies chosen can be useful for future implementations and features of the system.

5.9.1 Bluetooth

Bluetooth is a globally used wireless communication system that uses radio waves to transmit information from one device to another over short distances. This form of wireless communication is low cost and very low power consuming. Bluetooth operates through the master slave structure and can connect with up to seven devices in a closed scattered piconet. A visual representation of the master-slave relationship can be seen below in Figure 5. This communication method operates in the two point four gigahertz frequency band and the current version (4.0) can transmit data at twenty-four Mbits/s. Each Bluetooth device has a unique forty-eight bit address that is used to identify the device.

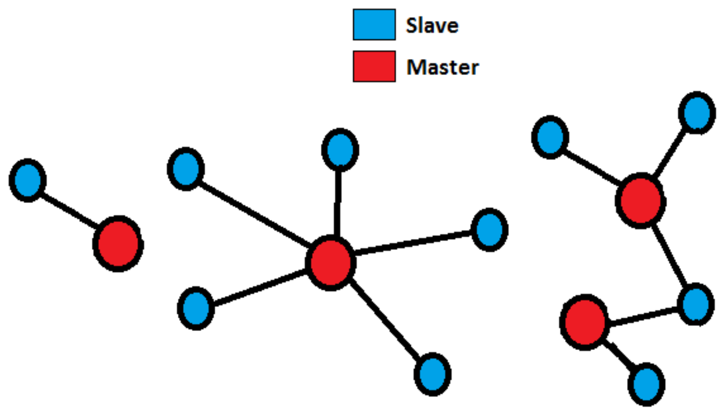


Figure 5 – Bluetooth Communication Structure

There are three classes of Bluetooth devices. Class one devices are mainly for industrial purpose and have the largest range. Class two devices are typically used in mobile devices and for common everyday use, having the mid-level range. Class three devices have the shortest range of the Bluetooth classes. A breakdown of these classes can and more details about them can be seen in Table 7.

Class	Max. Permitted Power	Range
1	100 mW or 20 dBm	~100 m
2	2.5 mW or 4 dBm	~10 m
3	1 mW or 0 dBm	~1 m

Table 7 – Classes of Bluetooth

5.9.2 3G/4G

3G communication stands for the third generation of mobile technology and goes by the International Mobile Telecommunications-2000 (IMT-2000) specifications set forth by the International Telecommunications Union. 3G was first released in nineteen ninety-eight and is a standard typically applied to cellular devices and supports a data transfer rate of at least two hundred Kbits/s. IMT states that the IMT-2000 standards provide a minimum data transfer rate of two Mbits/s for stationary users or three hundred forty-eight Kbits/s for moving users. A breakdown of technologies that fall under 3G can be seen in Table 8, additional information such as download/upload speeds can also be found here.

	Standard Type	Download Rate	Upload Rate
3G	UMTS	384 kb/s	64 kb/s
	W-CDMA	2 Mb/s	153 kb/s
	HSPA 3.6	3.6 Mb/s	348 kb/s
	HSPA 7.2	7.2 Mb/s	2 Mb/s
Pre-4G	HSPA 14	14 Mb/s	5.7 Mb/s
	HSPA+	56Mb/s	22 Mb/s
	WiMAX	6 Mb/s	1 Mb/s
	LTE	100 Mb/s	50 Mb/s

Table 8 – 3G Data transfer rates

In the case of WiMAX and LTE, the maximum data transfer rates vary with the user's movement. When a user is moving at a faster speed, the data transfer rates will be slower. This will not be an issue for design because, to access and transfer the data files, the user will be in a fixed position within close proximity of the device.

4G is the fourth generation of wireless mobile communications technology and must adhere to ITU specifications outlined in the IMT advanced standards. The ITU standards specifying 4G specifications were released in two thousand eight and set the data transfer requirements at one hundred megabytes per second for fast moving users and one gigabyte per second for slow moving or stationary users. The use of 4G technology requires a SIM card, which is already standard in all modern cellular devices, and a transceiver in the microcontroller of the transmitting device.

Depending on the implementation and requirements, both 3G or 4G could be used. For comparison a table (Table 9) describing the differences between 3G and 4G is provided below.

Comparison chart

	3G	4G
Data Throughput	Up to 3.1Mbps with an average speed range between 0.5 to 1.5 Mbps	Practically speaking, 2 to 12 Mbps (Telstra in Australia claims up to 40 Mbps) but potential estimated at a range of 100 to 300 Mbps.
Peak Upload Rate	5 Mbps	500 Mbps
Switching Technique	packet switching	packet switching, message switching
Network Architecture	Wide Area Cell Based	Integration of wireless LAN and Wide area.
Services And Applications	CDMA 2000, UMTS, EDGE etc	Wimax2 and LTE-Advance
Forward error correction (FEC)	3G uses Turbo codes for error correction.	Concatenated codes are used for error corrections in 4G.
Peak Download Rate	100 Mbps	1 Gbps
Frequency Band	1.8 – 2.5 GHz	2 – 8 GHz

Table 9 – 3G and 4G Comparison

5.9.3 Wi-Fi

Wi-Fi stands for Wireless Fidelity; it is a connection that uses radio waves to provide network connectivity to many devices. The wireless frequencies used in Wi-Fi range between two point four gigahertz and five gigahertz this depends on the amount of data on the network and supporting devices. Wireless networks is known as 802.11 networking or Wi-Fi. It is one of the IEEE technologies (IEEE 802.11). Many devices are compatible and use Wi-Fi including, but not limited to smartphones, advanced printers, game consoles and laptops. It is also compatible with almost every operating system that it used in the market.

Wi-Fi works similar to mobile phones. Radio waves are used to transmit information across devices. The 802.11 standard varies depending on what the user requires. 802.11a and 802.11n will transmit data at a frequency of five gigahertz. 802.11a uses Orthogonal Frequency-Division Multiplexing (OFDM), this is used to enhance reception by dividing the radio signals into smaller signals before they reach the source. Fifty-four and one hundred forty megabits per second are supported in 802.11a and n respectively. 802.11b and g will both transmit data at a frequency of two point four gigahertz which is a slow speed. 802.11b supports transmission speeds of up to eleven megabits per second. 802.11g supports up to fifty-four megabits per second because it uses (OFDM) technology.

Connecting to a Wi-Fi device usually goes in this form. A wireless client connects to an access point, this can be either a router, or another computer or device on the network. This is done through an access point. A device on the network acts as an access point for other to connect to it. After the connection is established network resources such as files and internet connectivity can be shared among devices.

For the Game Feeder Cam one of the considerations of the project is to use Wi-Fi for faster data rate between the devices being to communicate. Wi-Fi is used worldwide, but it is not a way to connect remotely to a device since Wi-Fi range is limited. Some Wi-Fi networks have range of up to one hundred fifty feet. Wi-Fi is one of the considerations of this project. It can be used alongside any of the application methods mentioned above. Connectivity to the microcontroller is key for transferring the information gathered by the GFC. Using Wi-Fi for short range communication would work for faster data transfers. Table 10 shown below, provides a breakdown of the different branches of Wi-Fi and the specifications.

Wifi Standard	Max Data Transfer Speed	Max Range
802.11a (5 GHz)	54 Mb/s	390 ft.
802.11b (2.4 GHz)	11 Mb/s	460 ft.
802.11g (2.4 GHz)	54 Mb/s	460 ft.
802.11n (2.4 GHz or 5 GHz)	300 - 900 Mb/s	820 ft. (2.4 GHz) or 460 ft. (5 GHz)
802.11ac (5 GHz)	433 - 1733 Mb/s	Up to 820 ft.

Table 10 – Wi-Fi Standards Comparison

5.11.4 Zigbee

Zigbee is a radio communication type that was developed as an alternative to Wi-Fi. Zigbee follows the IEEE 802.15.4 standard and was meant to be a very low power consuming and low cost communication type. Zigbee is a mesh networking type with the capability to reroute if one node stops working. Zigbee, much like many other communications methods, operates in the two point four gigahertz frequency range. The drawback of Zigbee technology is that it has a very low data transfer rate. The highest functioning Zigbee unit that was a consideration to implement was XBee. For transferring larger image files, the low data transfer rate is a large drawback and consideration in choosing a wireless communication method. Additional Figure 6 provides extra information and a visual representation.

- Support for multiple network topologies such as point-to-point, point-to-multipoint and mesh networks
- Low duty cycle – provides long battery life
- Low latency
- Direct Sequence Spread Spectrum (DSSS)
- Up to 65,000 nodes per network
- 128-bit AES encryption for secure data connections
- Collision avoidance, retries and acknowledgements

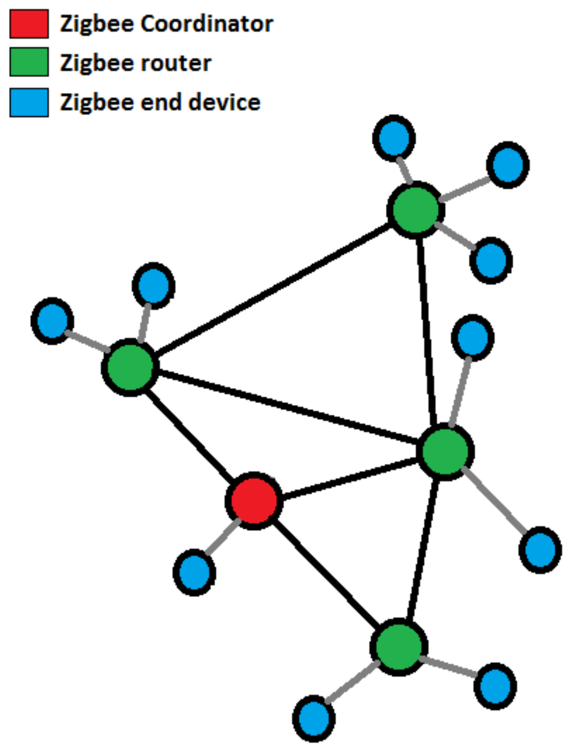


Figure 6 – Zigbee Mesh Network

5.11.5 XBee

XBee is a line of radio modules for communication developed by Digi International and are regulated under the IEEE 802.15.4 standard for point to point and star communications. XBee operates at the two point four gigahertz frequency and comes in XBee, XBee PRO (S2), and XBee PRO (S2B). These options offer a chip integrated antenna and are twenty pin through-hole modules. The outdoor line if sight range for the XBee is up to four hundred feet and for the

XBee PRO increases to up to two miles. The XBee unit is typically used with the Arduino microcontroller and many people have had a lot of success pairing these two for use in designing systems. Table 11 shows different implementation of XBee that can be used.

	XBee	XBee PRO (S2)	XBee PRO (S2B)
Outdoor line of sight range	400 ft.	2 miles	2 miles
Transmit power output	2 mW boost mode enabled	50 mW	63 mW
Data Throughput	35000 bps	35000 bps	35000 bps
Receiver Sensitivity	-96 dBm boost mode enabled	-102 dBm	-102 dBm
Supply Voltage	2.1 – 3.6 V	3.0 – 3.4 V	2.7 – 3.6 V
Operating Transmit Current	40 mA @ 3.3 V	295 mA @ 3.3V	205 mA up to 220 mA
Operating Receive Current	40 mA @ 3.3 V	25 mA @ 3.3 V	47 mA up to 62 mAwith
Idle current	15 mA	15 mA	15 mA
Operating Temperature	-40 to 85 C	-40 to 85 C	-40 to 85 C

Table 11 – XBee Tech Specs Comparison

5.11.6 Electric Imp

Electric imp is a communications solution that looks very similar to an average SIM card. It is a connectivity platform that utilizes Wi-Fi to connect to the imp Cloud without the need to set up a router. It features an imp Open API for the use of messaging and monitoring that may be useful in the implementation of the feeder system. It is a programmable device that can be used for a number of different Wi-Fi enabled features. The card itself contains a Wi-Fi module and a programmable processor. Programming and development on this device is done through a language called Squirrel, which is similar to the C programming language. Electric Imp also offers WEP, WPA, and WPA2 security encryption and can be bought for thirty dollars and the reader for use in microcontrollers is around fifteen dollars.

5.9.5 Cellular Communication (GSM / CDMA)

For the system requirement of sending custom alerts via text message, cellular communication is a key role in getting this goal done. Sending text messages requires service from a cellphone provider. There are many cellphone providers that would provide the sufficient services to accomplish this task. Presently carriers use one of the two technologies. GSM and CDMA are the networks to choose from. Both networks will provide text, voice, and data. Of course there are some similarities between these two types of networks. They also have their own advantages and disadvantages. Below the following technologies are discussed.

5.9.5.1 GSM

GSM stands for Global System for Mobile Communication, it is a digital mobile telephone system that is used in many parts of the worlds. Mobile services using GSM technology were first introduced in Finland in nineteen ninety-one. In present day there are around six hundred ninety mobile networks providing GSM services across the world. GSM represents eighty-two point four percent of all mobile connections worldwide. China is the largest GSM market with more than three hundred seventy million users. The US has around seventy eight million users. GSM uses a variation of time division multiple access (TDMA). GSM is the most widely used technology out of three available, GSM, CDMA, and TDMA. GSM compresses data and then follows to send it down a channel with two streams of data. Each stream of data is in its own time slot. GSM operates at the nine hundred megahertz or eighteen hundred megahertz frequency bands.

GSM services work with a Subscriber Identity Module (SIM) card; this holds the home networks access configurations. Many GSM carriers have roaming agreements with foreign carriers, this allows users to travel and still be able to use their phone services in other countries. SIM cards switched to metered local access, this reduces costs while roaming and still gives the user access to their services.

GSM forms part with many other technologies to be the evolution of wireless mobile telecommunications. These technologies include the following: High-Speed Circuit-Switched Data (HSCSD), General Packet Radio System (GPRS), Enhanced Data GSM Environment (EDGE), and Universal Mobile Telecommunications Service (UMTS). GPRS and EDGE were both used to send data over the wireless mobile carriers. GPRS is a packet data service used with 2G and 3G cellular communication systems. Data speeds ranged from fifty-six to one hundred fourteen kilobytes per second. EDGE is also used on top of GSM networks. It is around three times faster than GPRS. The data rate for EDGE ranges from one hundred thirty-five kilobytes per second (common) to four hundred seventy-three kilobytes per second (if used with eight time slots). Some of these technologies are still being sued, but many are now slow compared to the current technologies available. With many of its technologies GSM continues to be used worldwide.

There are many GSM carriers that can be used for the purpose of the GFC. In the US the two major GSM cell phone providers are AT&T and T-Mobile. They both offer multiple plans offering unlimited talk, text, and some even data. For the purposes of the GFC talk and data are not the essentials needed. Even with that thought in mind the most popular plans available will offer a combination of the three. Table 12 shown below will summarize the best plans that are available with different providers.

AT&T	Aside from the popular AT&T monthly plans they also offer a pay as you go service called GoPhone. GoPhone works as a prepaid month to month service and has many different plans depending on the needs of the user. Their current plans are: Unlimited Talk and Text with 5GB of Data for $60/Mo Unlimited Talk and Text with 2GB of Data for $45/Mo Unlimited Talk and Text with optional data for $30/Mo Unlimited Talk and Text with optional 100MB for $2/day Talk $.25/minute and $.20/text.
T-Mobile	Similar to AT&T, T-Mobile also offer pay as you go plans aside from their popular monthly plans. Their current plans are: Get any combination of 30 minutes or 30 text messages for $3/Mo 1GB of Data for $10/Week Unlimited Talk and Text with 3GB of Data for $40/Mo Unlimited Talk and Text with 5GB of Data for $50/Mo Unlimited Talk and Text with 10GB of Data for $60/Mo
Cricket Wireless	Cricket is owned by AT&T and they are a cell phone provider that offer monthly cell phones plans without annual contracts. Their current plans are: Unlimited Talk and Text with 2.5GB of Data for $40/Mo Unlimited Talk and Text with 5GB of Data for $50/Mo Unlimited Talk and Text with 10GB of Data for $60/Mo
Straight Talk Wireless	Straight Talk is a cell phone provider by TracFone Wireless. Their service works with most AT&T phones (GSM) and some Verizon phones (CDMA). Their current plans are: 1500 Minutes of Talk and Unlimited Text with 100MB of Data for $30/Mo Unlimited Talk and Text with 5GB of Data for $45/Mo Unlimited Talk and Text with 10GB of Data for $55/Mo
Go Smart Mobile	Go Smart Mobile is owned and operated by T-Mobile, but is sold as a separate and unrelated brand. Their current plans are: Unlimited Talk and Text with Unlimited LTE for Facebook, 3G Speeds for Data for $25/Mo Unlimited Talk and Text with Unlimited LTE for Facebook, 4GB of 3G Speeds for Data for $35/Mo

	Unlimited Talk and Text with Unlimited LTE for Facebook, 12GB of 3G Speeds for Data for $45/Mo

Table 12 – Comparison of Multiple Carriers and Service Plans

Out of the carriers and plans described above, we are considering Go Smart twenty-five dollars per month plan or T-Mobile's three dollars per month plan. These considerations are based on that most of the plans will include services (Talk and Data), that will not be used in the implementation of the GFC. Both of those plans would fall under the T-Mobile network. The plans will be considered and probably have to be tested to see which ones get better reception for the GFC. The GSM module that will be used by the GFC supports many GSM bands and each cellphone carriers supports different bands depending on the city. Consideration will be analyzed and a decision will be discussed in the communication sections of this document.

5.9.5.2 CDMA

CDMA stands for Code-Division Multiple Access, this refers to any of the many protocols used in 2G and 3G wireless communications. CDMA uses a form of multiplexing. This allows multiple signals to be in one transmission channel. This helps with the performance and usage of bandwidth available in the network. The operating frequencies are eight hundred megahertz and one point nine gigahertz bands, this is referred as Ultra-High-Frequency (UHF) telephone systems. Analog-to-digital (ADC) conversions are made in combination with spread spectrum with CDMA. Audio is first transform into digital binary codes. The frequency of the signal transmitted is then used to vary depending on the defined patter or code. This is done so that the transmission can only be received by a user that has the same frequency response (code). Privacy is made more secure and cloning is made more difficult to breach because there are many possible frequency-sequencing codes.

A CDMA channel is usually 123 megahertz wide, it uses a scheme called soft handoff. Soft handoff is used to minimize signal breakup as a device passes from one cell tower to another. In other words, a cell phone can simultaneously be connected to two or more cells. The use of digital and spread-spectrum modes helps support many more signals for the same bandwidth as analog modes use.

There are many standards that are used within CDMA. The original standard was known as CDMA One, it offered transmission speeds up to fourteen point four kilobytes per second with a single channel form and one hundred fifteen kilobytes per second with an eight-channel form. Other standards are CDMA2000 and Wideband CDMA, these deliver data much faster. The CDMA2000 is a family of standards that includes 1xRTT, EV-DO (revision 0), EV-DO (Revision 4), and EV-DO (Revision B – this was renamed to Ultra Mobile Broadband or UMB).

CDMA2000 should not be confused with CDMA. CDMA2000 is a set of standards supported by Verizon and Sprint) while CDMA is the actual multiplexing layer scheme. Verizon and Sprint are the two most popular cellphone carriers in the US that use the CDMA network.

5.9.5.3 Considerations

Some advantages of using a GSM network is that switching devices is simple since carrier information is stored on a SIM card. However, with CDMA this is not the case, carriers that use CDMA do not use SIM cards and still authenticate using their CDMA network. This means that switching phones will not be as simple. Also some carriers do not allow certain devices to be used. Using a GSM network allows for more freedom. CDMA offers better call quality and that is why many companies started using it. It also had more capacity. Most modern carriers are now using 4G LTE technology. This is a faster network that can transfer data at faster rates.

For the Game Feeder Cam, GSM technologies can be used in various ways. First it can be used to provide data features such as remote connectivity through the IP provided by the carrier network. It can also be used for text notifications. In the section of this paper for software implementations it was discussed that remote connectivity was a consideration for this project. As discussed above this has its disadvantages and advantages towards the project. A compromise to always using data is to use a GSM network to send various custom text notifications for various activities that the GFC will be able to perform. Going with this Idea the GFC would be able to transfer data remotely, but text notifications would give the status of how the GFC is doing.

5.7 Hardware

5.7.1 Microcontroller

Arduino Uno: The Arduino Uno, released in two thousand five, is a microcontroller that was intended to make a simple and cost-effective board to communicate with sensors, actuators, and other devices. The Arduino Uno's design was based on the ATmega328 board and operates using two parts, the microcontroller and an Integrated Development Environment (IDE) that is used to program the circuit board. Arduino Uno is highly useful because, instead of using a programmer, the code can be loaded into the board quickly and easily using USB. The hardware and software of the Arduino Uno are open source, so resources for this microcontroller are readily available and easily adaptable, also being compatible with both C and C++ programming. These microcontrollers are available for purchase on Adafruit for between twenty-five dollars and seventy-five dollars. The Arduino Uno consists of fourteen digital input/output pins, six analog inputs, seven to twelve volts DC input power input, a USB transfer connection, a sixteen megahertz quartz crystal, a reset button, and an ICSP header. The operations of these fourteen de() functions and these pins each operate at five volts. Table 13 shows the technical specifications associated with the Arduino Uno.

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 13 – Arduino Uno Specifications

Raspberry Pi: Raspberry Pi is a credit card sized microcontroller that is complete with a processor and the programming functionality of a small computer. Raspberry pi was released in two thousand twelve from the United Kingdom and was released to be a mini sized low cost fully functioning computer. This microcontroller consists of a Broascom system on a chip (SOC), an ARM compatible CPU, and an on chip graphics processing unit (GPU). The newest version of this microcontroller to be released comes with a quad-core CPU and 1 GB of included RAM. The operating system for the Raspberry Pi unit is called Raspbian, which is a free operating system based on Debian. This operating system is optimized for use on this microcontroller, but it is compatible with select other operating systems including Arch Linux and Ubuntu. Raspberry Pi can be purchased on Adafruit for the low price of forty dollars. Raspberry Pi B+ 2.0 comes with a forty pin GPO header as well as quad USB ports, Ethernet, and many other features for the use of programming this microcontroller to suit the needs of the feeder implementation.

- SoC: Broadcom BCM2836 (CPU, GPU, DSP, SDRAM)
- CPU: 900 MHz quad-core ARM Cortex A7 (ARMv7 instruction set)
- GPU: Broadcom VideoCore IV @ 250 MHz
- More GPU info: OpenGL ES 2.0 (24 GFLOPS); 1080p30 MPEG-2 and VC-1 decoder (with license); 1080p30 h.264/MPEG-4 AVC high-profile decoder and encoder
- Memory: 1 GB (shared with GPU)
- USB ports: 4
- Video input: 15-pin MIPI camera interface (CSI) connector
- Video outputs: HDMI, composite video (PAL and NTSC) via 3.5 mm jack
- Audio input: I^2S
- Audio outputs: Analog via 3.5 mm jack; digital via HDMI and I^2S
- Storage: MicroSD
- Network: 10/100Mbps Ethernet
- Peripherals: 17 GPIO plus specific functions, and HAT ID bus
- Power rating: 800 mA (4.0 W)
- Power source: 5 V via MicroUSB or GPIO header
- Size: 85.60mm × 56.5mm
- Weight: 45g (1.6 oz)

Beaglebone Black: Beaglebone Black is a microcontroller that is a single board computer, complete with processor much like the Raspberry Pi. This small computer was first released in two thousand thirteen and is produced by Texas Instruments along with Digi-key and Newark element fourteen. This board was developed for the purpose of college use and has open source software and hardware, making software and hardware easily available and adaptable. This board comes with a one gigahertz ARM Cortex-A8 Processor, five hundred twelve megabytes of DDR3L RAM, two times PRU thirty-two-bit microcontroller, boot button, and a reset button. This board comes programmed with the Debian GNU/Linux operating system, but is compatible with Android and Ubuntu as well. It has forty-six pins on each side capable of a large number of programmed features and comes with a USB port and Ethernet for connection purposes. Table 14 shows the tech specs of the Beaglebone Black.

Processor	Sitara AM3359AZCZ100, 1GHz, 2000 MIPS
Graphics Engine	SGX530 3d, 20M Polygons/S
SDRAM Memory	512MB DDR3L 400MHz
Onboard Flash	2GB, 8-bit Embedded MMC
PMIC	TPS65217C PMIC regulator and one additional LDO
Debug Support	Optional onboard 20-pin CTI JTAG, Serial Header
Power Source	miniUSB or DC Jack; 5VDC External via Expansion Header
PCB	3.4" x 2.1"; 6 Layers
Indicators	1-Power, 2-Ethernet, 4-User Controlled LEDs
HS USB 2.0 Client Port	Access to USB0, Client mode via miniUSB
HS USB 2.0 Host Port	Access to USB1, Type A Socket, 500mA LS/FS/HS
Serial Port	UART0 access via 6 pin 3.3V TTL Header (header is populated)
Ethernet	10/100, RJ45
SM/MMC Connector	microSD, 3.3V
User Input	Reset Button, Boot Button, Power Button
Video Out	16b HDMI, 1280x1024 (max), 1024x768, 1280x720, 1440x900 w/EDID Support
Audio	Via HDMI Interface, Stereo
Expansion Connectors	Power 5V, 3.3V, VDD_ADC (1.8V); 3.3V I/O on all signals; McASP0, SPI1, I2C, GPIO(65), LCD, GPMC, MMC1, MMC2, 7 AIN (1.8V max), 4 Timers, 3 Serial Ports, CAN0, EHRPWM (0,2), XDMA Interrupt, Power Button, Expansion Board ID (up to 4 can be stacked)
Weight	1.4 oz (39.68 grams)
Power	210-460mA@5V (depending on activity and processor speed)

Table 14 – Beagelbone Specifications

Arduino Mega2560: The Arduino Mega2560, is a microcontroller unit based in the ATMega2560 and has 54 Digital input/output pins, sixteen analog inputs, four UARTs, a sixteen megahertz crystal oscillator, a USB connection, an ICSP header, and a rest button. These fifty-four input/output ports can be programmed to perform a variety of different functions using the pinMode(), digitalWrite(), and digitalRead() commands. Using the analogWrite() function, this board can be programmed to provide 8 bit PWN output as well. The tech specs for the Arduino Mega Microcontroller are shown in Table 15. This microcontroller is much like the

Arduino Uno microcontroller, but with more advanced and updated features for higher functionality than its more basic counterpart. It is programmable by the same Arduino software that the Arduino Uno uses and comes standard with a bootloader allowing the user to upload new code without using an external hardware programmer and uses the original STK500 protocol in communication. An outline of this protocol released by Atmel is available in pdf format from the Arduino website.

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Table 15 – Arduino Mega 2560 Specifications

5.9 Feed Container

When choosing a feed container, there are two main considerations: the capacity of the container and the material of which it is made of. After looking at what was available on the market, further research of the options is needed because if the feed housing is inadequate, the rest of the features will not matter.

Material: The two main materials for feed containers used are metal and plastic. The market seems to be split in their offering of plastic and metal containers with the main difference being price. Although the weights differ between specific manufacturers, the average fifty five gallon metal drum weighs forty pounds and the plastic alternative weighs about twenty pounds. The GFC will be outside the majority of its life enduring the elements so durability is important. While metal containers are susceptible to rusting, it can be minimized by coating the bare metal in paint. The plastic containers may not rust but they will dry rot in the sun even though some of the better models are UV resistant. Plastic containers are also prone to holes due to hungry animals such as squirrels which are known to gnaw on the plastic in an attempt to reach the feed inside.

Size: The size of the feed container is one of the determining factors to how often the feed will need to be replenished. There are many sizes available on the market varying from about twenty to six hundred pounds of feed. To calculate the capacity of feed the type of feed must be known. The most common feed used is corn so the calculations for the GFC capacity will be based on the density of US corn number one. A fifty five gallon drum is capable of carrying about zero point two zero eight one nine eight cubic meters and the corn used has a volume of about seven hundred and twenty two kilograms per cubic meter. This transfers to a maximum capacity of approximately one hundred sixty one kilograms or three hundred fifty five pounds, so the labeled maximum capacity provided on the GFC will read three hundred ten pounds to account for any fluctuation in corn size. The fluctuation in size is due to the origin of corn used by the feed companies, the worst case calculation listed on the page achieved an approximate maximum fill of three hundred ten pounds.

5.10 Feed Container Stand

Because the GFC will use a combination gravity and mechanical feed distribution system, the feed container will need to be elevated. Elevating the feed container will allow ample room for the feed distribution system as well as the added benefit of keeping the system out of reach from hungry animals. The following are the possible choices to implement on the GFC.

Tripod: The tripod feeder design for the GFC design would require the purchase of mounting brackets to affix the three metal poles to the fifty-five gallon drum. This is a basic design used by many sportsmen because of the portability and ease of assembly out in the field. Figure – 7 Tripod feeder shows what this setup would look like. One drawback can be observed from this system which is the need for a ladder or elevated platform to reach the lid to fill the drum once it is elevated.

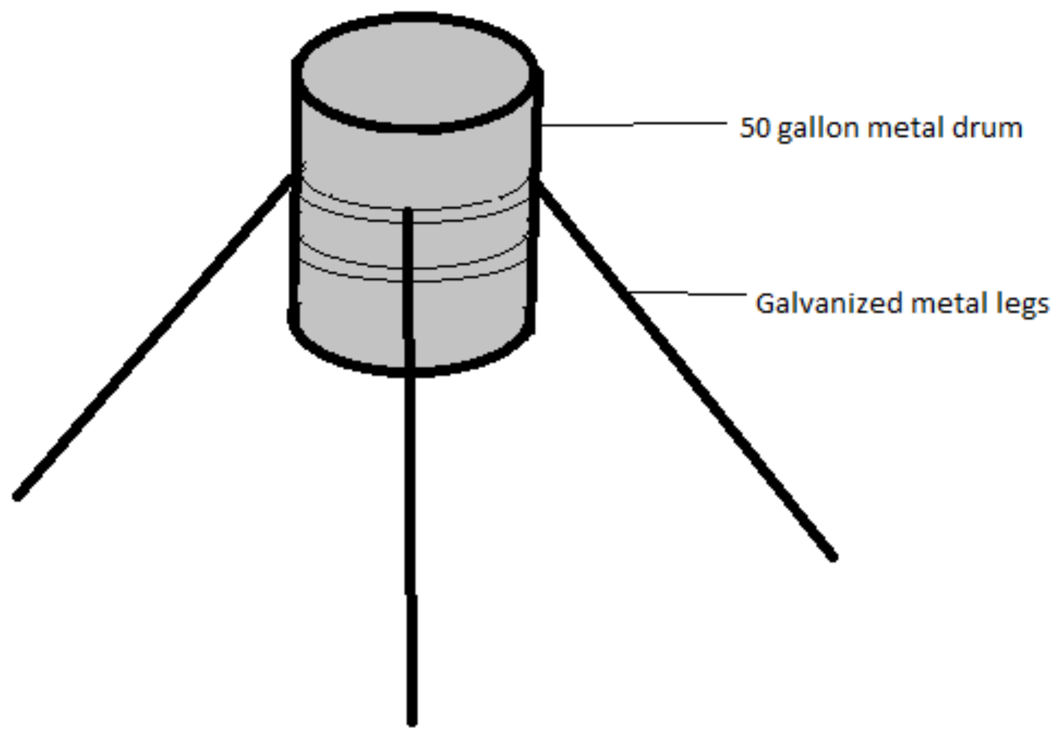


Figure 7 – Tripod feeder

Hanging: A hanging system in comes in a couple of variations depending on the capacity of the feeder being used. Due to the size of the GFC's three hundred and ten pound capacity, utilizing a tree limb in any fashion to suspend is unrealistic unless there are substantially large trees in the area. Another method for hanging is a frame that uses a winch system to raise and lower the feeder container inside as seen in Figure 8 – Hanging Feeder. This system makes refilling the feeder easy but the setup is more difficult and adds the danger of a winch and cable.

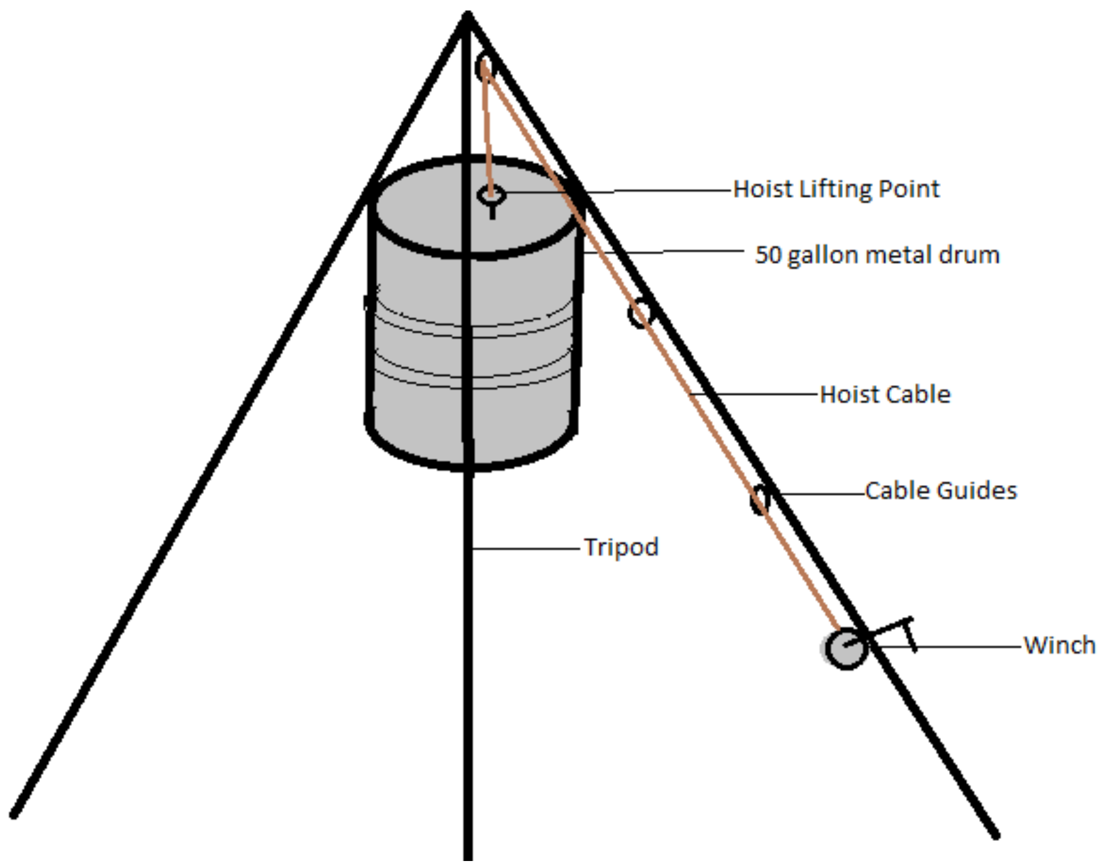


Figure 8 – Hanging feeder

Modified: The last category considered was a modified stand which in most cases looks similar to Figure 9 – Modified Stand, which shows a ladder and platform incorporated into the feeder stand. This allows the sportsmen to both hunt from the stand as well as provide an easy way to reach the lid of the drum to refill the feed. To allow for the added weight of the sportsmen in addition to the complete feeder, most of these systems have four legs and the drum will sit inside an exoskeleton housing.

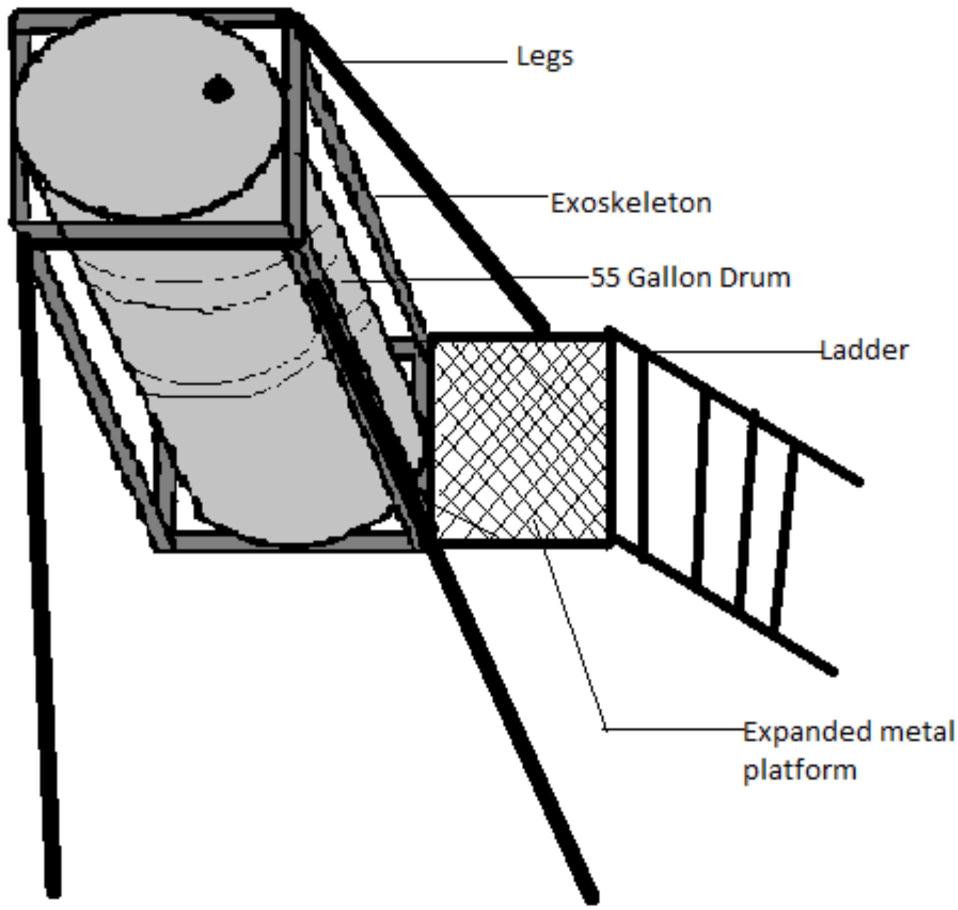


Figure 9 – Modified Stand

5.13 Decision Criteria and Justification

During initial prototyping and schematic design, some problems arose with some ideas proposed in the initial Divide and Conquer paper. These problems were addressed and altered. Only after all initial prototyping was complete were these changes finalized.

In the beginning, the GFC was to have a servo controlled feed door opener to allow feed to fall from the drum onto the feed disc. A CAD program was going to be used to create a feed disc and housing out of plastic to have a fully redesigned system. After looking into the time and cost associated with CAD drawing and printing a new design, it was decided to utilize a system already available rather than reinventing the wheel. The servo idea was scrapped due to added cost as well as increased probability of mechanical failure.

The camera placement has been change multiple times throughout the design process. It started as a three hundred sixty degree camera mounted on top of the

GFC. This idea was changed when the actual cost and success of implementation was researched. Version two was multiple cameras mounted either on the top or bottom of the GFC cage, this was also found to be very costly. A final decision was made to mount a servo to the bottom of the GFC and the camera will hang from it. This method will cover approximately two hundred forty degrees which is still greater than the one hundred eighty-degree coverage available on the market.

5.14 Overall System and Associated Diagrams

For the feeder application's architecture the system will be using a mix of layering and repository styles. The layering style representation is used because the data will have to go through multiple layers and processed individually at each specific layer. Upon reaching the lowest layer, the I/O, Bluetooth/Wi-Fi, sensors, and camera. Management components will begin to interface with the actual mobile device and Feeder. When the information is finally processed it will go to the user layer which can branch out into many differ states depending on the option screens selected.

5.14.1 Component Block Diagram

The block diagram shown in figure 10 is being used as the basis for work distribution and to layout the major components that need to be implemented to have a fully working system.

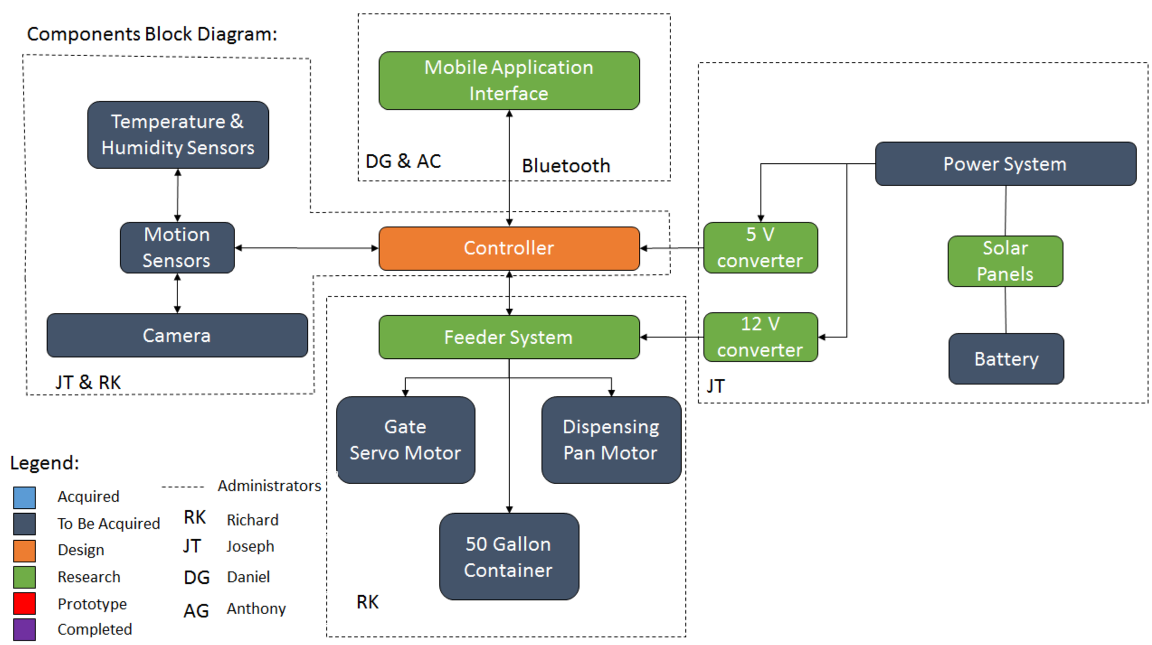


Figure 10 – Component Block Diagram

The diagram above gives a visual representation of how each component should be integrated to work with other components.

5.14.2 Software Block Diagram

The software block diagram shown in figure 11 gives a full breakdown of how the software implementation should work. The development process should integrate these features for the GFC to be a working product.

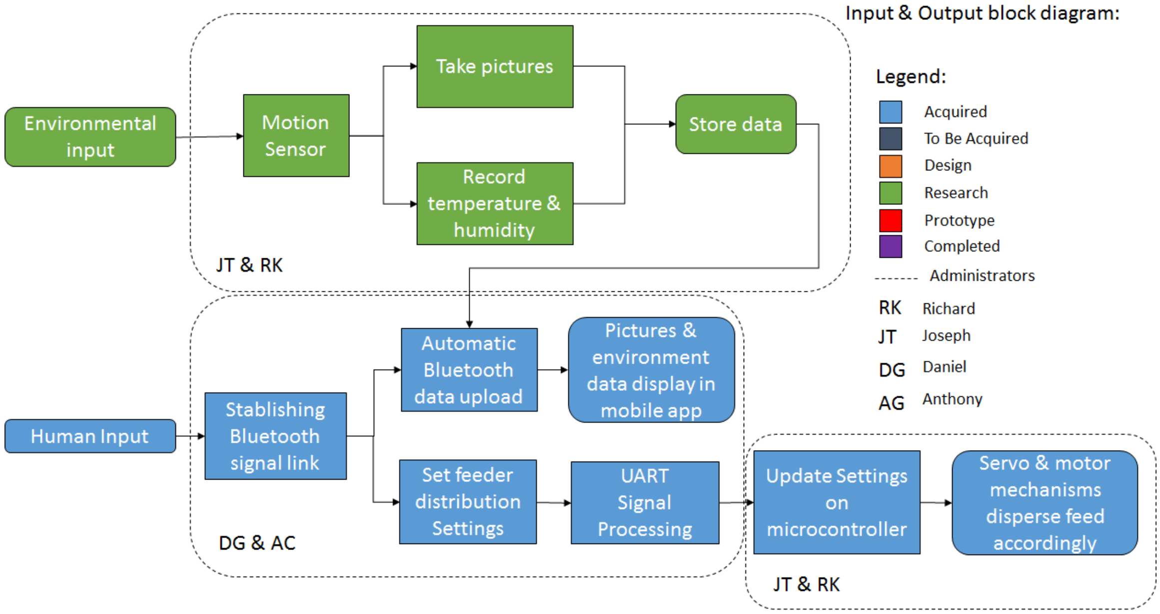


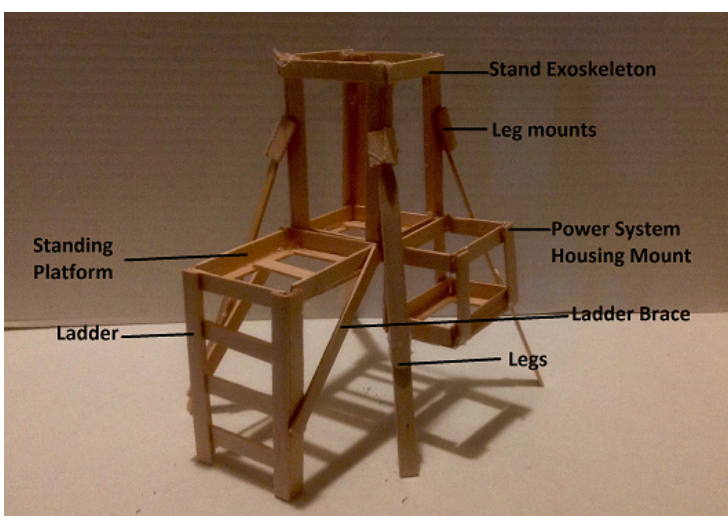
Figure 11 – Software Block Diagram

6.0 Physical Design

Physical design will cover the component housings, the feed stand, and all mechanical assembly of the GFC. Everything will be done in house except for the welding, which was done with the help of welding instructor. The instructor taught as well as helped with the welding and fabrication of the stand.

6.1 Feeder and Stand

The GFC will utilize the modified stand and a used fifty five gallon food drum. The stand will be made of metal and welded together in a way to keep it portable. The welder, Karl Clements, requested a physical mock up for the stand production. Figure 12 - Stand Prototype and Final Assembly is the model we delivered to begin mockup of the GFC stand and the final product. The standalone sections will be the exoskeleton with leg mounting holes, standing platform, ladder, ladder braces, legs, and drum. The legs will be attached to the exoskeleton by sliding them into the six inch recessed holes on each of the four corners at a twenty-three degree angle. The ladder will be attached to the platform on a lip formed with angle iron. The roof for the solar panel will be elevated five feet above the bottom with angle iron, this will ensure clearance to refill the corn in the drum. When the entire stand is assembled with the ladder it is in the feeder filling setup. When leaving the GFC behind the sportsman will take the ladder off of the platform and conceal it within the vicinity of the GFC. This will allow the camera to take pictures in this quadrant without the ladder being in the background.



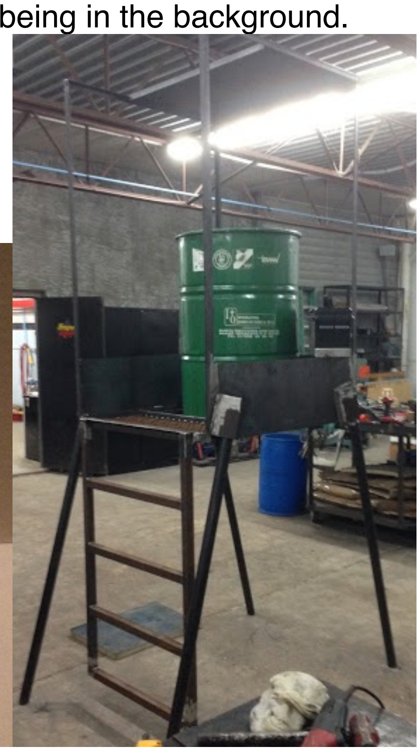


Figure 12 – Stand Prototype and Final Assembly

6.2 Motor and Main Component Housing

The GFC feeder system housing is a repurposed American Hunter Wildlife Feeders brand RD-PRO Digital Feeder kit pictured below in Figure 13 - Feed System. Figure 12 shows the housing and housing cover separate to illustrate the breakdown to begin disassembly.

Disassembly: To further disassemble the housing, the small diameter shaft, a Phillips head size zero screw driver is required. There are four screws located on the top of the funnel of the feeder housing that need to be removed to access the feed disc screw. After removing the top funnel, loosening the feed disc screw and removing the feed disc, a flat head screw driver is needed to pry out the digital time panel. There are two wires connecting the digital timer to the PCB board for power and two that lead to the motor. A soldering iron and solder sucker are needed to de-solder the power board and the motor. Using an electric three eights inch chuck drill and a three thirty second inch metal drill bit, the rivet will need to be drilled out to remove the power board. Lastly, the motor will be reused in the project but it does not have a data sheet on file so testing will be required, which makes it necessary to remove the motor. This is achieved by unscrewing the two screws holding it to the top of the housing while holding the motor to ensure it doesn't drop out freely. Figure 14 - Disassembled Feed System shows from left to right, the feed funnel that mounts to the bottom of the feed container and the four screws that attach it to the main housing. Next, the motor face on view showing the two mounting screws and behind the motor is the feed distribution disc. Third from the left is the stripped housing with metal varmint guard attached to the top. The old battery hold down, battery contact PCB and the digital timer that were removed to make room for the new electronics. Lastly, the battery and digital timer housing was cut down on three sides to allow room for the MCU PCB and the fourth side was left to attach the motor control PCB.

Figure 13 – Feed System

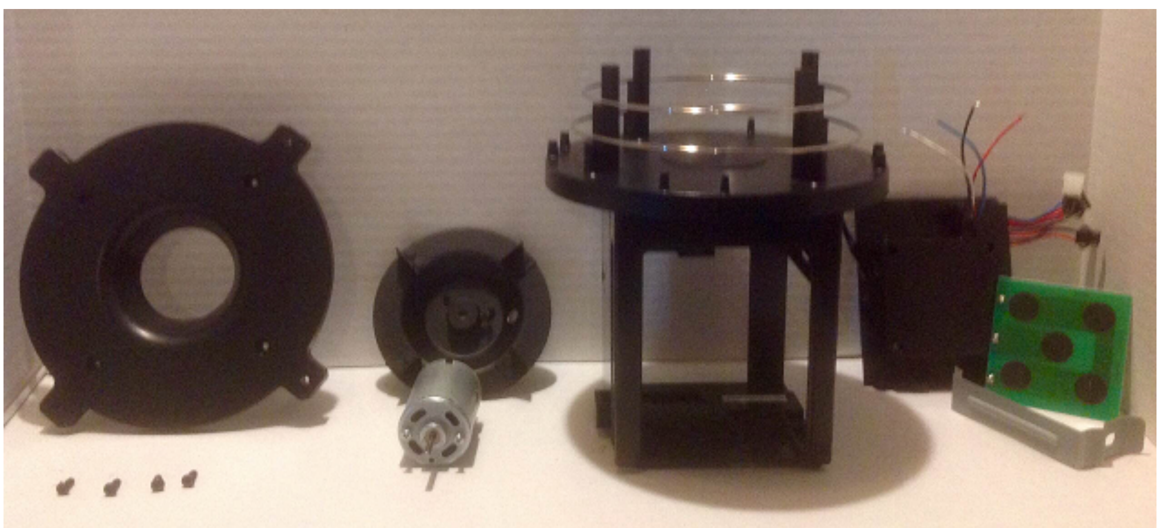


Figure 14 – Disassembled Feed System

Assembly: Reversing the steps of disassembly the motor, feed disc, and top funnel will be installed. Now using a Dewalt jig saw cut a piece of one eight inch piece of plywood the diameter of the housing container and affix to the bottom of the container with hot glue. The MCU PCB will mount to the piece of plywood via wood screws. The motor control PCB will mount next to the motor on the fourth side left during disassembly. Every measure is being taken to reduce effect of the noise and heat generated by the DC motor system on the MCU and communication modules.

6.3 Power System Housing

The power system housing is a re-purposed fifty caliber plastic ammo container as seen in Figure 15 - Power System Housing. The container has a rubber gasket to keep moisture out and a double latch to securely close the lid. While these containers are offered in both metal and plastic, plastic was chosen to avoid any shorts due to future wear and tear on the electronics such as frayed wires. The battery will mount on the bottom of the container while the PCB and wire buses will mount on plastic boards cut to fit on the top rim.

Figure 15 – Power System Housing

6.4 Weather System Housing

The sensors, due to their operation, will need to be mounted outside the main electronic housing. The length of wire used affects the error due to noise so care will be taken to locate them as close as possible to the main PCB while allowing the sensors access to the outside environment.

Weather Sensors: The weather sensor system PCB will be mounted to the outside of the main electronic housing cover seen in Figure 13 - Feed System and a small one quarter inch hole drilled to allow the wires to pass through from the MCU PCB which will have a silicon bead around it to keep weather out of the main electronics housing. There will be a cover mounted over the PCB to keep direct weather elements off of the circuitry as seen in Figure 16 - Weather System Housing.

Housing construction: As seen in figure 16, the housing will be constructed of electrical conduit and PVC. Using the data gathered in prototyping the weather system on the Perf-Board, the housing will be a one and a half inch three way electrical conduit junction box. The bottom will be capped with a hole in the center to allow the wires to pass through. The sides will have forty-five degree elbows mounted downward to allow airflow but prevent water damage. Each of the pieces will be affixed using PVC primer first then PVC glue.

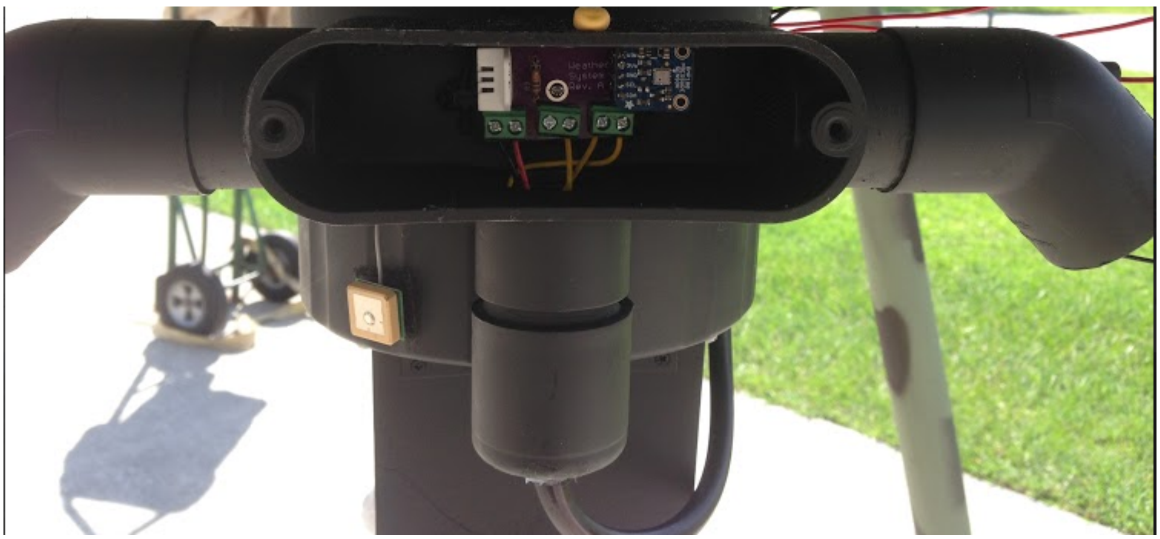


Figure 16 – Weather System Housing

6.5 Camera System Housing

After determining that multiply cameras and or the three hundred sixty degree camera would cost much more to implement than originally calculated a single camera system was created. The new design requires some extra components but overall it will save on the total cost of project. The camera system housing will mount to the bottom of the motor and main component housing, eliminating the problem in the original design of access to the feed container fill lid.

Camera System: This system was designed to allow the camera to move to all four defined quadrants via servo rotation. As seen below in Figure 17 - Camera System Housing Side View the servo mounts with four bolts to the bottom of the frosted acrylic. It will need a slot one half inch by three inches to flush the mounting holes of the servo with the frosted acrylic. Then a three inch diameter circular piece of acrylic will be cut using a Dremel tool with a circle cutter and a cutting bit. This acrylic disc will mate the servo to the camera with four bolts from servo to acrylic and an additional four bolts from camera to acrylic. A small one quarter inch hole will need to be drilled in the bottom of the housing to allow the wires of the camera to pass through. Tests will be run to determine the length of wire required to leave hanging for unimpeded movement to all quadrants.

Motion Sensors: The motion sensors chosen will mount on the frosted acrylic camera system housing with the sensor exposed and backside of the sensor in the enclosure. A bead of silicon will seal the sensor into the housing, which will protect the electric components on the backside as well as the remaining PCBs on the inside of the enclosure. Each of the four sensors will be mounted in a seven sixteenths inch hole, drilled dead center of each side. This will provide detection for each of the four quadrants.

Housing Construction: The camera system housing was constructed from an old Go Pro container. Brass hinges were affixed to one side and a latch to the opposite. A brass hook watch screwed into the main housing for the latch to attach to. After testing and final prep, the top will be attached, all holes and joints will have silicone or gaskets applied to prevent weather from damaging the internal electrical components.

Figure 17 – Camera System Housing Side View

6.6 Solar Panels

The solar panels will be mounted with the included hardware to the top of the feeder stand roof. At this point in time there will be one solar panel mounted to support the battery charging system, which is subject to change in the future. The wiring for the solar panels will be run down the inside of the angular metal upright columns in PVC tubes to prevent chaffing of the wires over time.

7.0 Hardware Design and Schematics

The hardware design and schematics required the analysis of the given components data sheets to come up with a feasible schematic which were created in Eagle CAD. Eagle CAD was used because the schematics can be used directly to create the board layouts.

7.1 Feeder and Camera System

The feeder components make up five subsystems which are the weather sensors, motor and control system, camera and control system, Bluetooth module and GSM/GPS module. The Bluetooth module and GSM/GPS module will not have schematics provided since they are being bought as stand-alone modules while the remaining subsystems will have schematics drawn out to show the intended design. After survey and considerations of previous senior design teams' experiences on PCB manufacturers, OSH Park was selected as the primary choice for to send the board layout for printing. After receiving the boards testing was done and only one problem found which could be design error with a voltage divider. Further testing is required to fully understand whether it was manufacturing or design error.

7.1.1 Weather Sensors

The two sensors chosen are described in detail below the schematic diagram figure. Both are populated on a PCB board and powered by the power supply unit (PSU) for the senor PCB, stepping the voltage down to five volts which is sufficient for both sensors. The schematic and final PCB design in Figure 18 - Weather Sensor Schematic and Final PCB design shows the complete layout of the board and the final product.

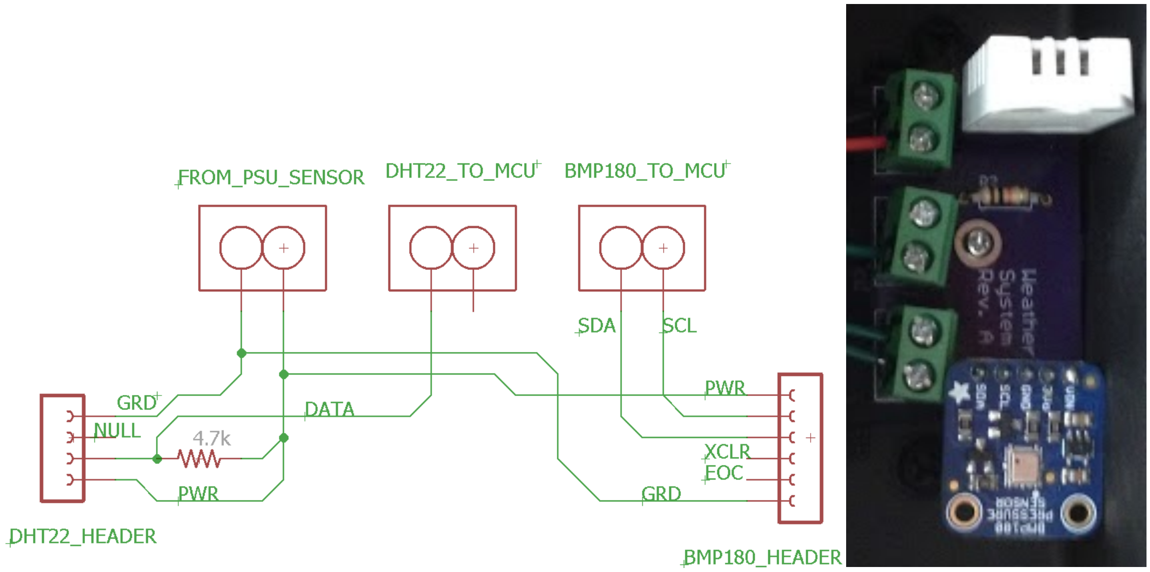


Figure 18 – Weather Sensor Schematic

Schematic and PCB: As seen in the schematic, the printed-circuit board (PCB) has female headers for the DHT22 and the BMP180 to plug into. The DHT22 has four pins out: power, ground, null and data. The data pin pushes the readings back to the MCU and the null pin isn't used. A resistor is prescribed in the schematic to provide extra resistance for the pullup on. The BMP180 did not come with the male header pins so the pins were purchased dipped in flux and soldered to the board allowing it to be plugged into the female header on the main sensor PCB. Two pin screw terminals were used to ensure a secure connection to both the main MCU PCB and the senor PSU board.

BMP180 Barometric Pressure/Temperature/Altitude Sensor: This sensor is analog requiring the use of analog pin in number four which is for data and pin number five for the clock. It requires a three point three volt power source and without an onboard regulator it will need a voltage regulator, to step down the voltage. The pressure sensing range is three hundred to eleven hundred hectopascals (hPa) from nine thousand to negative five hundred meters above sea level at up to zero point zero three hPa per one quarter meter resolution. The temperature sensor operates from negative forty to eighty five degrees Celsius but is plus or minus two degrees Celsius in accuracy. Because the temperature is not as accurate as the DHT22 sensor, the temperature readings from the BMP180 will not be polled. The BMP180 uses piezo-resistive technology to read the pressure and altitude.

DHT22 temperature-humidity sensor: Using a capacitive humidity sensor and thermistor temperature sensor the DHT22 uses three to five volts to operate and a max two and a half milliamp draw. The humidity sensor reads zero to one hundred percent humidity with two to five percent accuracy while the temperature sensor detects temperatures from negative forty to eighty degrees Celsius with plus or minus on half a percent accuracy.

7.1.2 Camera Sensors

After deciding not to use six positioned cameras with built in motion sensors, an external sensor was needed to detect the quadrant to rotate the servo and camera system. After viewing and initially picking a pre-made PIR module, it was found that the available products have an operating temperature range up to twenty degrees Celsius. After further research and analysis, a sensor with a greater operating temperature range up to sixty degrees Celsius was found. The Panasonic NaPiOn series has a model which also far exceeded the detection range and angle seen in the pre-made models. The ten meter detection model in analog was chosen but because the sensor comes with just a three leg design, it the decision was made to make a breakout PCB for each sensor, which would allow for a cleaner look inside the housing and the ability to affix the board securely to the inside of the housing with a cutout hole to expose the sensor. Shown below in Figure 19 - Motion Sensor Schematic is the design to be utilized in all four of the sensors. There was an option between active and passive infrared sensors but because the average detection window of the active sensor was sixty degrees, it was decided that the window should be greater than that of the camera which is sixty degrees. The tradeoff will be that the passive infrared sensor is known to produce false triggers, resulting in extra pictures without an animal. Below Figure 19 is Table 16 - AMN24112 NaPiOn Specifications which is the specifications to ensure the proper PSU as well as the performance specifications, which supports the theory that it is the best product to use for this application.

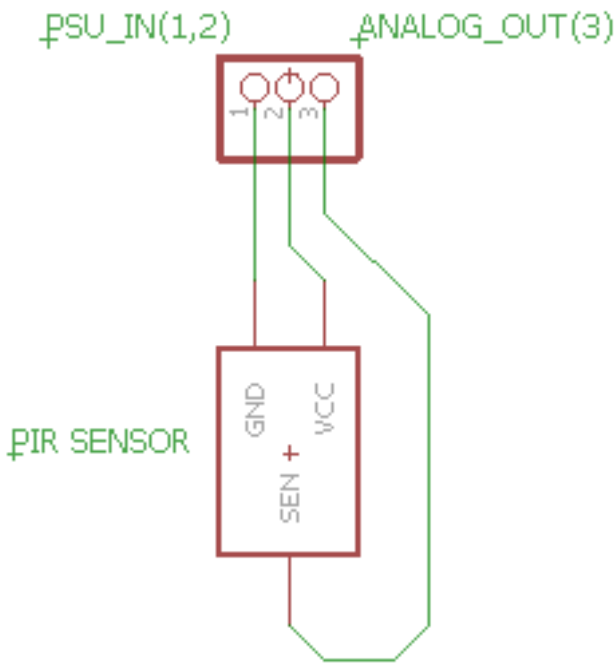


Figure 19 – Motion Sensor Schematic

Item	Value
Usage temperature range	–20 to 60°C
Detection range (Horizontal × Vertical)	110° × 93°
Detection distance	10m
Consumption Current	170µA
Output Current	50µA
Operating Voltage	4.5VDC min. 5.5VDC max.

Table 16 - AMN24112 NaPiOn Specifications

7.1.4 Motor and Control

As a cost savings measure, the GFC will reuse the motor that was purchased in the feed system housing as well as the funnel and disc. Because the funnel to disc system is being used, the motor shield will not be needed for the additional control of a servo controlled feed door. The Adafruit Motor/Stepper/Servo Shield costs nineteen dollars and ninety five cents plus tax while the components to build the simple motor controller from the analog PWM pin out on the Arduino Mega2560 costs much less. Because the motor didn't come with a data sheet, testing will be conducted to determine a slow, medium and fast speed. The PWM values were tested at six volts and slow was tested at a value of one hundred fifty, medium was two hundred and two hundred fifty five is the fastest speed available. The embedded code used to control the Arduino Mega2560 is described in the software section below under motor control. In order to design the motor control and PSU the amperage draw of the motor needed to be tested, the results are below in Table - 17 DC Motor Amperage Testing. Motor testing was conducted with a Keithley Triple Channel Power Supply using channel three set at six volts and five amps. The peak draw with disc and no disc was determined after using the highest initial reading during ten cold starts, meaning the motor was left to sit for one hour between starts, connected directed to the power supply. The simulated corn load was created by applying light pressure to the bottom of the disc and the peak draw was the peak draw reached after applying the pressure.

Test Performed	**Amperage Draw Average (Amps)**	**Amperage Draw Peak (Amps)**
No Load	0.429	0.449
Feed Disc	2.351	4.785
Feed Disc Simulated Feed Load	3.704	3.901

Table 17 - DC Motor Amperage Testing

Schematic: After testing was performed it was determined that an N-channel MOSFET part number FDS8984 was needed to replace the BJT that the original schematic called for. This MOSFET will handle just above the load amperage draw determined during testing at seven amps but because the maximum turn-on voltage is two and a half volts and the typical voltage is one point seven volts. It will require a voltage divider circuit to reduce the voltage coming from the PWM pin on the MCU. The Figure 20 - Motor Control Schematic and PCB below shows the circuit designed with the PCU in to provide six volts to the motor and the final PCB. To come up with the voltage divider circuit, the voltage in is required for a designated voltage out. The MCU was tested and confirmed that the voltage out on the digital PWM pin was limited to five volts. This was done by running a test PWM program and measuring the voltage across a one-thousand-ohm resistor, which was four point seven five volts. After plugging the values into the equation with the input voltage at five volts, output voltage at two volts and resistor number one value of fifteen hundred ohms, and the resistor number two value was found to be one thousand ohms.

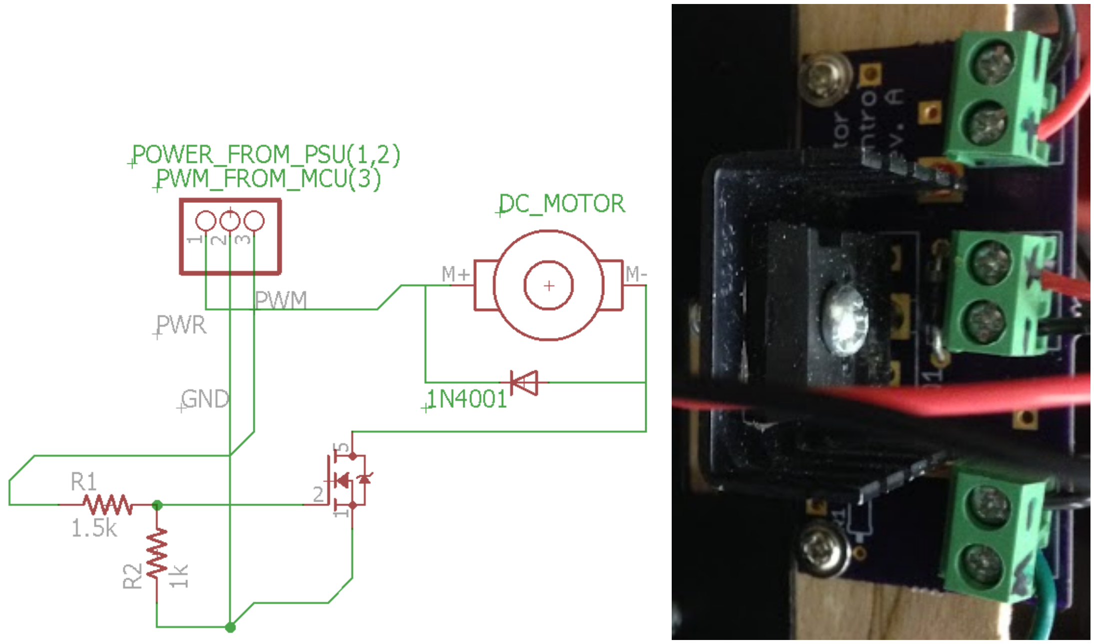


Figure 20 –Motor Control Schematic and PCB

7.1.5 Arduino Mega 2560 Rev3

The Arduino Mega2560 microcontroller was chosen in our design due to the fact that it has more RX and TX pins than the Arduino Uno, which was the original microcontroller that we anticipated using. When trying to incorporate the camera unit, the bluetooth module, the GSM/GPS module, and the barometric temperature and pressure sensor, the Arduino Uno did not have enough RX and TX pins to facilitate all of these components. We decided to use the Arduino Mega2560 microcontroller instead because of its increased connectivity and the increased functionality found in the Mega2560. It has a much higher Flash memory, SRAM, and EEPROM along with four UARTs versus one with the Uno. Overall the Mega2560 was much better suited to integrated assembly and the intended needs for the feeder system. Table 18 shown below provides a comparison between the Arduino Uno and the Mega.

	Arduino Uno	Arduino Mega 2560
Processor	ATmega2560	ATmega328P
Operating Input Voltage	5V/7-12 V	5V/7-12 V
CPU Speed	16 MHz	16 MHz
Analog In/Out	16/0	6/0
Digital IO/PWM	54/15	14/6
EEPROM	4	1
SRAM	8	2
Flash	256	32
USB	Regular	Regular
UART	4	1

Table 18 –Arduino Uno to Mega 2560 Comparison

7.1.4 Bluetooth Module

The Bluetooth module that we have decided on is the JY-MCU. This simple class two Bluetooth module has four pins: RXD, TXD, GND, and VCC. It has an operating VCC voltage of three point three volts and to the RXD pin a level conversion must be made in order to achieve this voltage. This is done by connecting a two point two kilo-ohm resistor to GND, a one kilo-ohm resistor to the Mega2560 MCU, and connecting the RXD pin of the JY-MCU in between these resistors to create a voltage divider. This will give the RXD pin the correct voltage for operation. Figure 21 provides a visual representation of how the Bluetooth module will be connected.

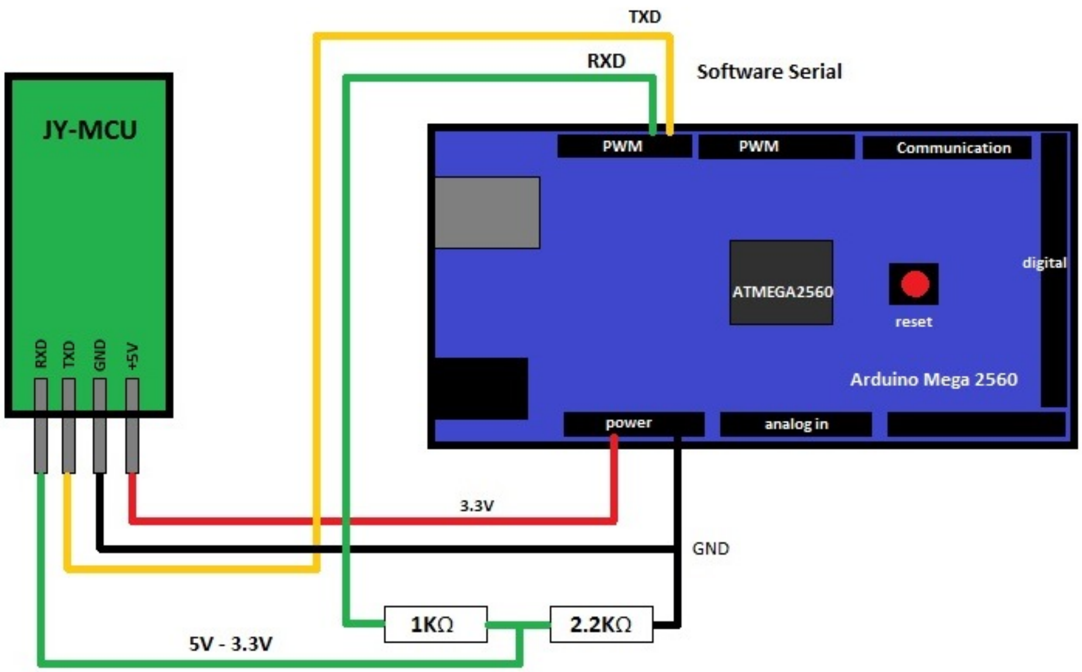


Figure 21 – JY-MCU to MCU Connections

7.1.5 GSM and GPS Module

Adafruit FONA 808 Cellular and GPS: This module incorporates cellular connectivity and GPS in one module. The Adafruit FONA 808 GSM module cost forty-nine dollars and ninety-five cents plus the cost of purchasing the external antennas and 2G SIM card. A passive GPS antenna and a GSM/cellular quad-band antenna were needed for connectivity of this GSM module. These will allow text notification capability as well as GPS location services. With quad-band functionality, this module can connect onto any GSM network with a 2G SIM card and operates in an input voltage range of three point four to four point four volts with very low power consumption. This module works specifically well with the chosen Arduino Uno microcontroller. With a battery power supply and external antenna, operation of this GSM module is simple and wiring this module into the Arduino Mega2560 requires connecting them as shown in Table 19.

GSM Module Output	Arduino Mega 2560
Vio	5V
GND	GND
Key	GND
RX	Digital input
TX	Digital input
RST	Digital input

Table 19 – GSM to MCU Connections

7.1.6 GSM Module Battery and Antenna:

In the Adafruit FONA 808 GSM and GPS module, an antenna for GSM functionality, a GPS antenna, and a battery are required for operation. We will be using the battery in the GSM module for testing purposes only. Adafruit offers a couple different options for each of these components.

GSM/Cellular Quad Band Antenna: These antennas are offered in both sticker type and with a SMA plug. The SMA plug type would require a separate SMA connector for use and the SMA plug antennas offer a two dBi gain versus the three dBi gain for sticker type antennas. We decided to use the Slim Sticker Type GSM/Cellular Quad Band Antenna for use with the FONA 808 GSM module.

GPS Antenna: The passive GPS antenna comes in either 9mm X 9mm size and offers a negative two dBi gain or in fifteen by fifteen millimeter size and offers a one dBi gain. The decision was made to go with the antenna that has the highest functionality for the GSM module and purchased the Passive GPS Antenne uFL in the fifteen by fifteen millimeter size size giving a one dBi gain.

Battery: Adafruit offers Lithium Ion polymer batteries and battery packs for use with the Fona 808 module. In the feeder design, the Lithium Ion polymer batteries are a much better choice than the battery pack option. All of the batteries operate at an output voltage of four point two volts when fully charged to three point seven volts, with widely varying capacities. The capacities offered are one hundred mAh, one hundred fifty mAh, three hundred fifty mAh, five hundred mAh, twelve hundred mAh, two thousand mAh, and twenty-five hundred mAh. The largest capacity battery would be the best choice due to the high frequency of use in the numerous notifications to the user. The three point seven volt twenty-five hundred mAh Lithium Ion Polymer battery was chosen for use in implementing the feeder design.

7.1.7 ESP8266 Wi-Fi Module

The ESP8266 Wi-Fi module is the module that will be used to transfer code to the Arduino Mega 2560 microcontroller. Using the connections shown in Table 20, this module works with the Arduino IDE to allow programming and data uploading to the microcontroller via Wi-Fi connectivity. This module operates strictly on a voltage of three point three volts, but this module uses more current than the three point three volt pin of the Mega2560 can supply. So a voltage divider must be used to convert the five volts power pin of the microcontroller to three point three for the ESP8266 to use. This can simply be solved by including an external three volts regulator. The operating current of this module ranges from sixty-two to two hundred fifteen mA and a standby mode current of zero point nine mA. The Wi-Fi feature of this module operates at a two point four GHz frequency and a baud rate of ninety-six hundred.

ESP8266	Arduino Mega 2560
Vcc	5V (with external regulator)
GND	GND
CH_PD	5V (with external regulator)
RX	TX
TX	RX
GPIO	GND

Table 20 – ESP 8266 to MCU Connections

7.1.6 SIM Card

In order to make the GSM module work, a SIM card is required along with a cellular service provider to provide cell phone tower usage. Access to the cellular tower provides this essential network connectivity and transmission of data. The SIM card that is required by the Adafruit FONA 808 GSM and GPS module is a 2G Mini SIM Card. Mini SIMs are one inch by one sixth of an inch, which is the most common and easy to find SIM card size. MicroSIMs are also widely sold, but will not fit into the FONA 808 GSM module. There are two providers that offer GSM compatible mini SIM cards, T-Mobile and Ting. T-Mobile's Sim cards are sold for twenty dollars as opposed to the much lower cost of nine dollars offered by Ting. We decided to purchase the Ting SIM card from the Adafruit website due to not only the cheaper cost, but they are recommended for use with FONA 808 GSM module as well. Activation of this SIM card requires calling Ting and giving credit card details and signing up for one of their offered plans. Once activated, installing the SIM card in the back of the FONA 808 module is the only thing needed in order to start using the mobile GSM network and have access to the cell phone towers.

7.1.7 Micro SD Card Breakout Board

In order to use an SD card for storage with the Arduino Mega2560, a Micro SD card breakout board was needed. We purchased this breakout board from Adafruit for eight dollars. The coding and libraries for SD card use with the breakout board will be discussed in section 7.2.10. This board has a built in dropout regulator that allows this board to work with both the five volt and three point three volt pins. The correct wiring of this breakout board to the Mega2560 is shown in Table 21.

Micro SD Breakout Board	Arduino Mega 2560
5V	5V
GND	GND
CLK	SCK
D0	MISO
D1	MOSI
CS	SS

Table 21 – Micro SD Breakout Board to MCU Connections

7.1.8 SD Card

SD cards come in two sizes from a variety of brands in a wide selection of sizes. The breakout board that is used with the Arduino Mega 2560 microcontroller only uses MicroSD cards instead of the standard larger size. The memory sizes and their storage capacities are shown in Table 22. The number of images that can be stored is estimated at the six hundred forty by four hundred eighty resolution, which is the largest resolution available, resulting in an average image size of about twelve and a half kilobytes per image.

SD Card Capacity	Image Capacity	Cost
4 Gb	~320,000	$4-$8
8 Gb	~640,000	$6-$10
16 Gb	~1,280,000	$6-$10
32 Gb	~2,560,000	$10-$16
64 Gb	~5,120,000	$20-$45

Table 22 – SD card comparison

In the selection of SD cards, there is not much difference in price between four Gb, eight Gb, sixteen Gb, and thirty-two Gb cards. For the price, the best selection of SD card for the purpose of large data storage is the thirty-two Gb SD card. These can easily be found on Amazon or a number of different places. The SD card that we purchased for this feeder is the thirty-two Gb SanDisk brand Micro SD card found on Amazon for thirteen dollars. This will more than be able to accommodate image and data storing needs and has a relatively low price, about the same cost or not much more expensive than other SD cards with a lower memory capacity.

7.2 Feeder and Camera System Integration

All of the components which makes up the feeder and camera system need to be connected and controlled through one MCU. The block diagram below in Figure 22 - Feeder and Camera System Integration to MCU shows the breakout of all that provides and receives information or control through the MCU. In the following sections, the MCU chosen will be discussed in detail and the schematic layout of the MCU will be provided.

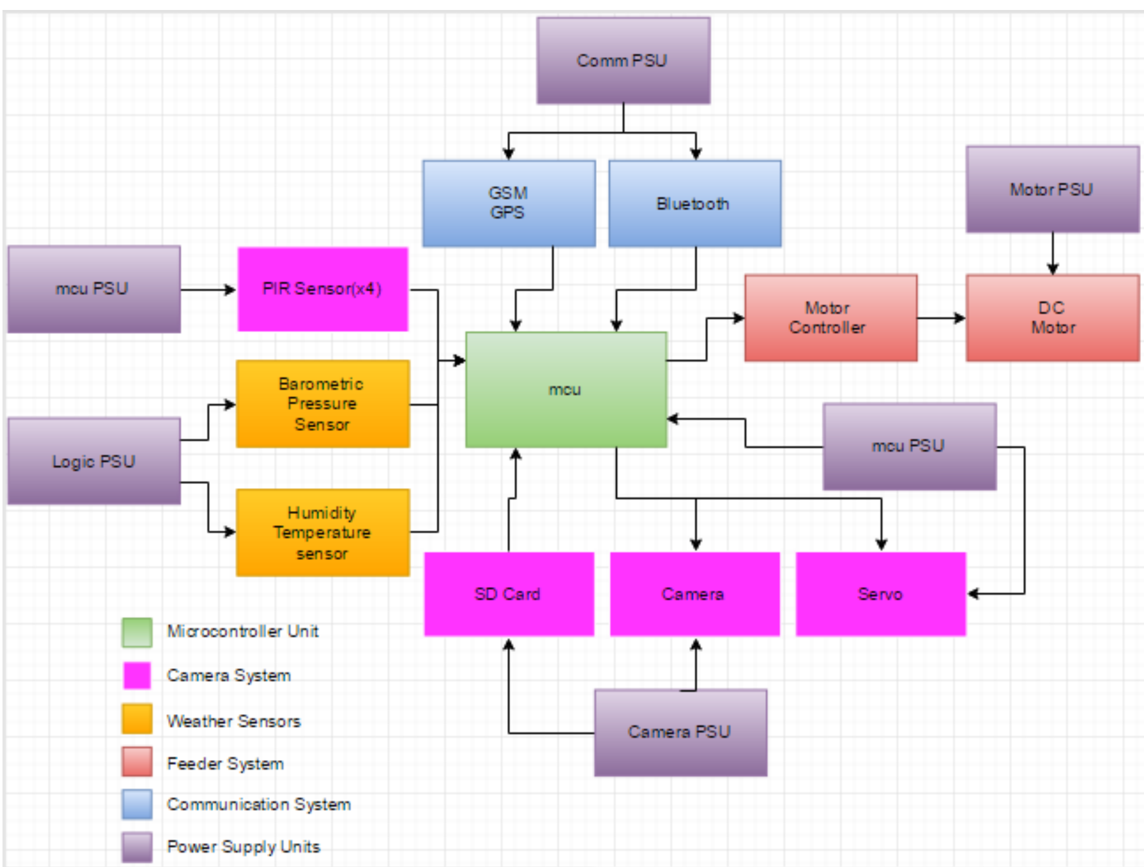


Figure 22 – Feeder and Camera System Integration to MCU

7.2.2 Camera system Design

For the camera system design on the game feeder we will use one weatherproof TTL Serial JPEG Camera that is sold by adafruit.com. As it was stated on the research conclusion due to a limited budget we could only afford one camera so other to have a the most visual area coverage of the environment the camera will be mounted on a continuous motion servo motor that will move the camera between four different quadrants the servo motor's motion will be controlled by the MCU that will send pulse with modulated signals to the motor that will be determined by the motion sensor system. For instance if the sensor for quadrant number two detects any motion activity the MCU will send the assigned modulated signal for quadrant number two to the servo which will then rotate to the predetermined degree and consequently quadrant consequently rotating the camera into quadrant number two. Once the camera is in the correct diagram it will take the picture send and send it to the MicroSD card module where it will be stored for retrieval later. Figure 23 below shows the schematic diagram and PCB of the camera system.

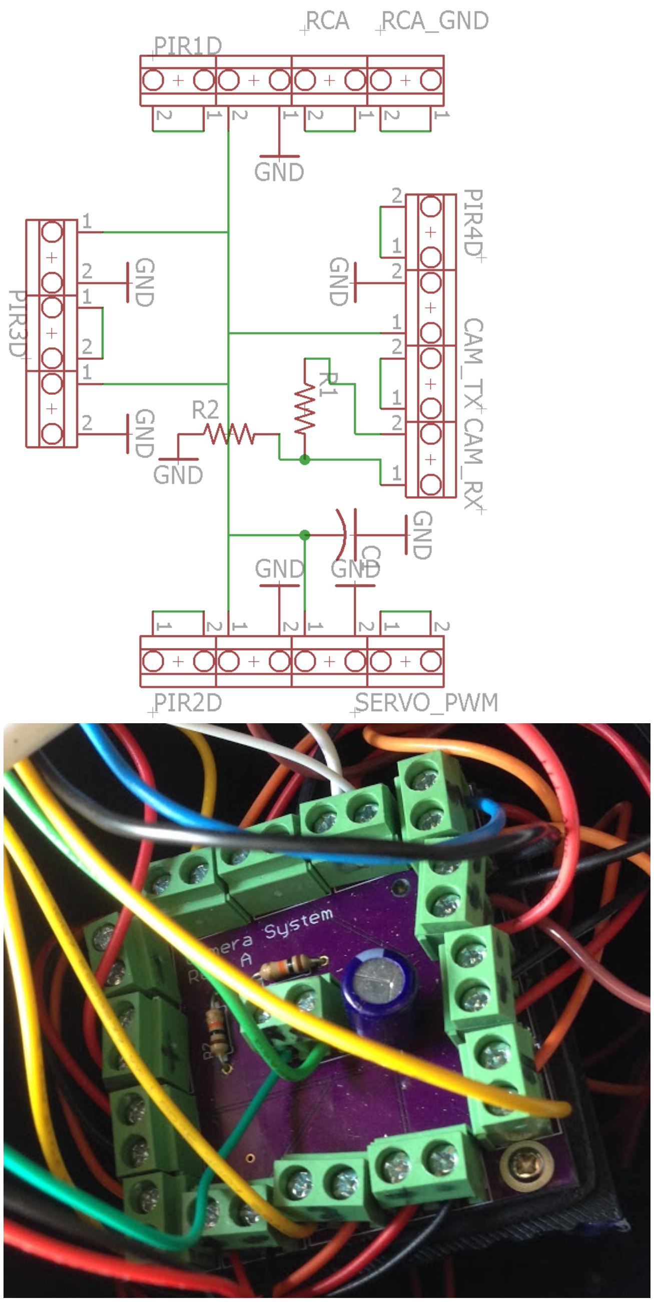


Figure 23 - The schematic diagram of the camera system and PCB

As you can see on the schematic all of the voltages in and grounds will be bussed together to the MCU since the entire camera system works off of five volts. In order to avoid the servo motor from moving erratically a four hundred seventy microfarad capacitor will be added in between its Voltage in and ground this is to avoid the servo from drawing too much power from the MCU board which could drop the voltage on it and causing it to reset. The servo motor will also have a signal terminal connected to the MCU which is how it will get the width modulated pulses. The camera module will be connected to an RCA video module in order for us to perform a manual focus of the camera. In order to adjust the camera focus we will have to remove the casing of the camera to gain access to the set screw as seen below in Figure 24 – Camera Focus Disassembly. Disassembly begins by first removing the camera mount and lens housing. Then unscrew the flash assembly and pull it off of the lens allowing access to the set screw. After the set screw is removed the focus can be adjusted manually while looking at the display. When the correct focus is achieved replace the set screw and reassemble the camera unit. Then the Tx pin (data from module) and the Rx pin (data into the module) will be connected into the MCU, with these pins the MCU will store the pictures indo the SD card and also determine from the ambient light sensor whether or not to use the built-in infrared LED flash. Finally the SD card's data in, data out, clk and chip/slave pins will also be connected to the MCU's hardware SPI pins in order to have the best performance out of them.

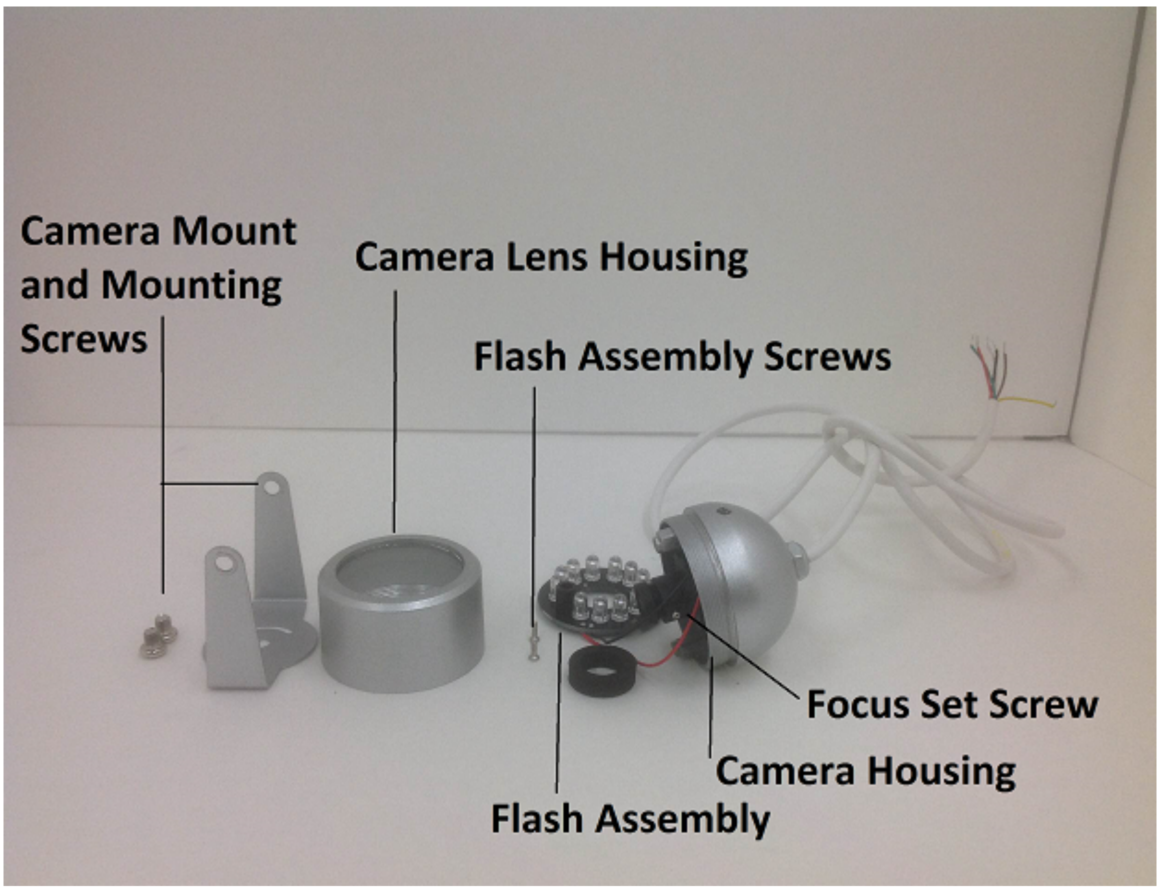


Figure 24 – Camera Focus Disassembly

7.2.8 Schematic Layout

After looking at the schematics and data sheets provided on the Arduino website the following schematic was created utilizing the necessary components for the GFC system. All the pins will run to connectors although they might not all be used. This will allow for future expandability without creating a need board. The schematics below show the necessary components being re-used from the original Arduino Mega2560 development board. The following two schematics shown in Figure 25 – Arduino Mega2560 Schematic and Figure 26 – Arduino Mega2560 PCB illustrate the components needed to utilize the Mega2560 MCU and the final PCB.

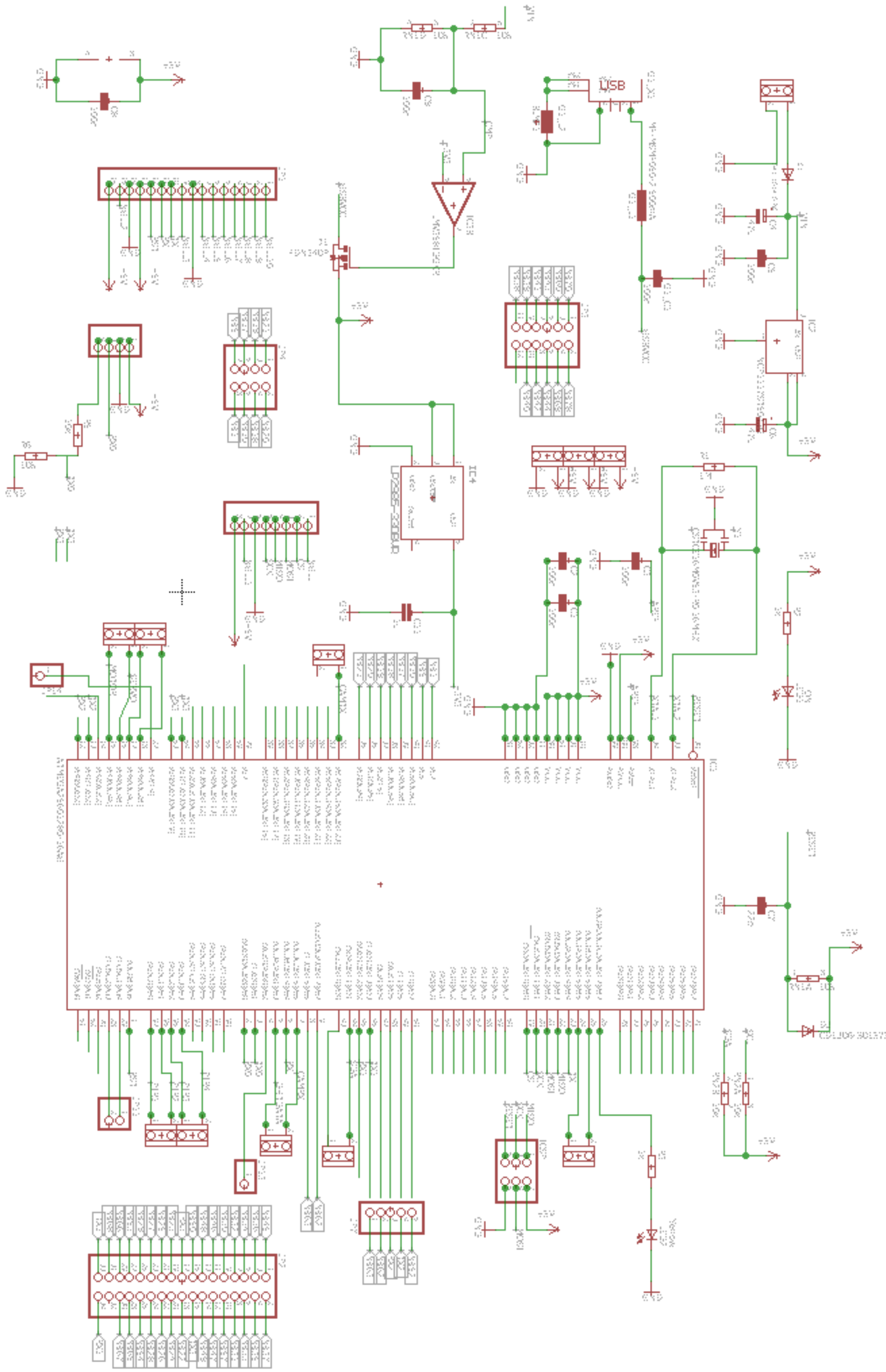


Figure 25 – Arduino Mega2560 Schematic

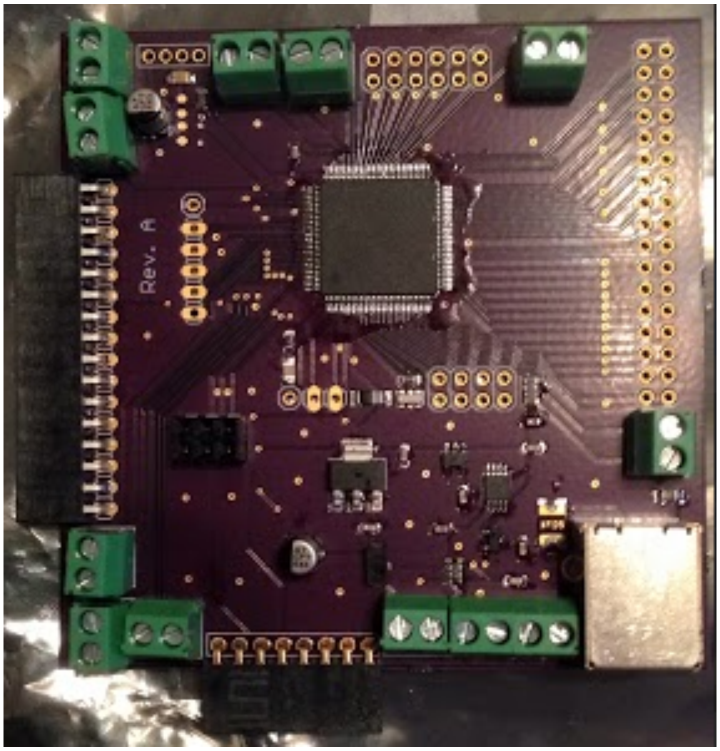


Figure 26 – Arduino Mega2560 PCB

The schematic below Figure 27 - Arduino Mega2560 USB Power System is the USB power system. This will be kept to do initial power tests after the PCB is printed and to power the PCB while loading the GFC software. The DC power system will be removed as well as the ATMEGA16U2-MU chip and its subsystem.

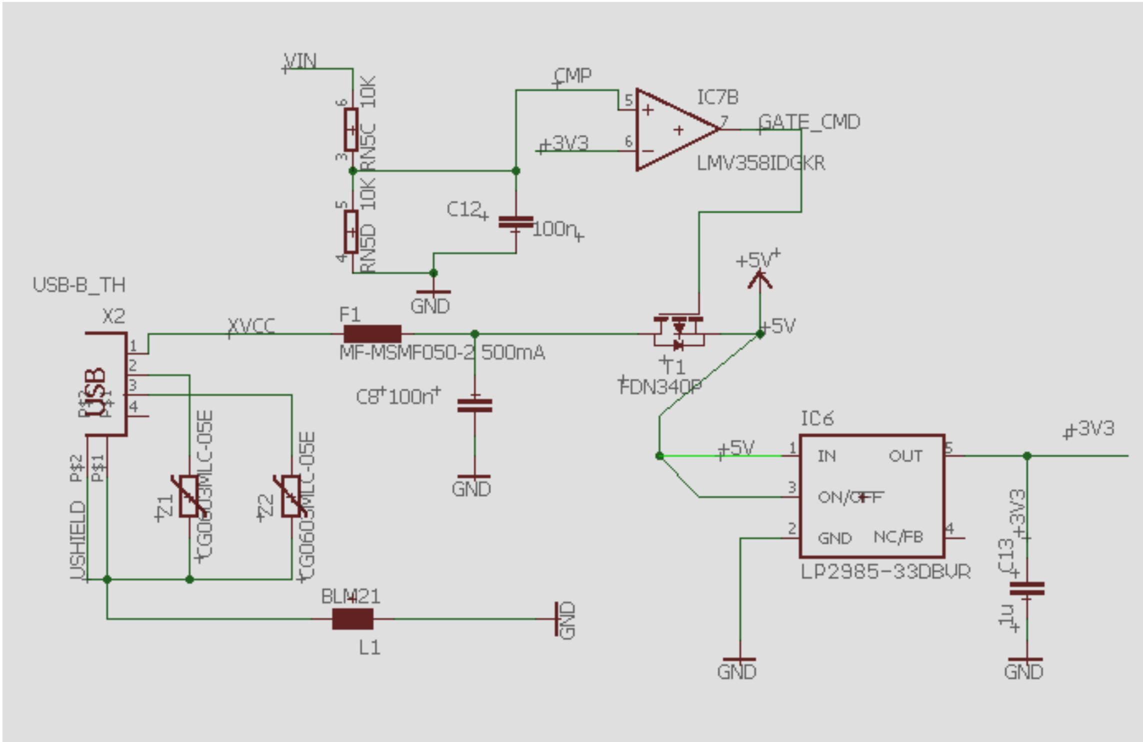


Figure 27 – Arduino Mega2560 USB Power System

8.0 Software Design

At this time the software implementation of the project has been completed to ensure functionality. In this final documentation many aspects of the software design will be discussed and explained in detail. The software design covered in this paper will cover the technologies that were used to develop and implement all the software features of the GFC. For designing the Game Feeder Cam project, we would like to control and customize many of the features in one place. This ensures a working and customizable product. For the project we worked on developing an Android application that changes the way the user can interact and use the GFC. The graphical user interface provides many features that can help the user comfortable with the application.

Many features of the GFC will be discussed in the following sections of the Software Design. The following sections will describe how the software will be implemented and what it should accomplish. The goal is to explain the features and implementation without the readers need to completely understand the programming languages and technologies used in the system. The goal of the software implementation is to have a system that interacts with an Android application to accomplish many tasks. We want to combine a printed circuit board (PCB), with many modules to interact with software and stay connected to notifications. This was achieved by interaction of the software running on the PCB and the functions added for interaction in the application. The next sections will cover the technologies that were used to accomplish these goals.

8.1 Android Application

The decision to develop an Android application was made because of compatibility with many devices. Many mobile devices are running the Android operating system. This means that many users who already own devices running Android can take advantage of the custom features. Since Android is an open-source OS there are many APIs that can be used. Also the Android software development kit (SDK) will be used to develop the application. The device running Android should be able to communicate with the GFC through Bluetooth. The API for Bluetooth connectivity between devices is provided by Google.

The application also has a graphical user interface (GUI) that will allow users to change settings such as, feeding schedule, text notifications, and motor speeds. The application also provides a photo gallery to allow pictures to be downloaded from the GFC. The download feature was implemented by downloading the pictures to the user's phone and store them in internal memory. In future updates this should be change to choose which picture to download. Many other additional features could get implemented if sufficient resources and time are available. One of the extra features can include live feed from the cameras. The following sections will discuss the set of tools that were used to implement the application.

8.1.1 Application Design

The design of the application is based on simplicity. We want users to open the application on their devices, change the settings they want, feeling positive that the changes have been made. A simple interface is key. The interface has the following sections:

- Picture Gallery: This is used to see the pictures stored on the SD card of the GFC. It will be used to download the pictures to the chosen device and also erase them from the SD card. As mentioned below the download feature is implemented automatically at this time. Also for the removal of the pictures a user can remove the GFC folder in their internal storage or simply press the remove picture button in the application to remove all pictures.
- Notification: Settings on how often a user would like to receive notification are found here. More information on the types of notifications will be discussed in a later section.
- Camera: This section is used to change camera settings such as quality. (NOTE: This section should be available in future updates of the application. For this functionality the GFC system program will also need to be modified.)
- Motor: The GFC supports different motor speeds and this section will allow the user to change those values.
- Feeding Times: In this section a user will be able to change what times the GFC will distribute the feed.

Each of these sections will be used to access or change a different feature of the GFC. Many more sections and activities can be included in future versions of the application. The hardware that was used can provide additional features and functionality to the application.

The reason for developing an application is to bring an easy to use product to the market. The mobile application industry is very popular and most are used to the concept of a mobile application. The application will not seem difficult to learn. The graphical user interface of the application will help users see and know what actions they want to accomplish. Many of the features of the GFC can be modified through the hardware. This can be a more tedious task for many users that just want a product to work and not mess with its internals. The application brings all of the settings that the product offers in one place. This is also being done so that the hardware internals of the system do not have be physically accessed for changes to take effect. The next sections will discuss how the implementation of the application design will be developed.

8.1.2 Application Implementation

The design of the application takes a combination of different technologies to be implemented and work together. The Android SDK is a key feature used to integrate all of these together. The next important technology that was used is Bluetooth. Bluetooth is being used to establish a connection to the GFC, which then can be used to change the settings that have been previously mentioned. Finally, a GSM module is being used for the notification system. The application communicates with the GSM module for notifications to successfully work. The implementation will be explained and diagrams will be provided to show the most important aspects.

8.1.2.1 Android OS and SDK

As mentioned above the method used to control the GFC is an Android application. Android is the best option because it is open source, and there are many resources available for development. Also compatibility with many devices. The Android application was written in the Java programming language. We are using Java because is the native language to run applications on Android. For the development environment Android Studio is being used to develop and design the application. For the development process the Android Software Development Kit (SDK) is being used as well as many other open source libraries. The Android SDK comes with Android Studio for a full toolset for developing a fully working Android application. The Bluetooth library is a big part of the GFC project. Bluetooth connectivity was established using the Bluetooth low energy library. The SDK is key to help develop an application that will be able to change some of the aspects that have already been discussed above.

8.1.2.2 Bluetooth Connectivity and API

The device (any device running Android that has working Bluetooth) running the GFC application should be able to wirelessly connect to the PCB/microcontroller. More information on the hardware being used to achieve Bluetooth connectivity will be covered in the Communications section of the Hardware Design. This section is here to explain how the Bluetooth connectivity will be achieved via the software aspect of the design.

The Android OS includes support for the Bluetooth network stack. This allows a device to exchange data wirelessly with other Bluetooth devices. Bluetooth functionality can be accessed through the Android Bluetooth APIs. Some of the features these APIs include is connection to Bluetooth devices, enabling point-to-point and multipoint wireless features. Using the Bluetooth API will enable the following features:

- Scanning for Bluetooth Devices
- Check the Bluetooth adapter for paired Bluetooth Devices
- Establish RFCOMM channels
- Connect to devices via service discovery
- Transfer data between devices.
- Manage multiple connections.

The Bluetooth APIs provide different variations depending on the needs. There is normal Bluetooth that is used for more battery-intensive operations such as streaming and communicating between Android devices. For Bluetooth devices with low power requirements another API was introduced for low energy Bluetooth. For the GFC the low power implementation will not be implemented. At the time of a Bluetooth connection the GFC will need to be able to transfer data (pictures and device information) to the device connected. The GFC is not a portable device meaning that Bluetooth will only be used when at closed range to the GFC. Battery performance should be able to handle the short term Bluetooth connection from device to GFC.

As long as a Bluetooth connectivity can be established between a device running the Android application and the GFC functionality should be achieved. This theory has not been tested since the full product hast not been assembled. Research has confirmed that an Android application can be used to send commands to an Arduino Uno via Bluetooth. Testing will be performed to make sure that the connection is strong. Since the Android application will get most of its information and data, Bluetooth connectivity is the key to its success. The following sections introduce many more features that will be implemented after Bluetooth connectivity is achieved.

8.1.2.3 Motor Speeds

The GFC also features a DC motor that is also customizable in speed. After a Bluetooth connection is established from the application to the GFC there will be a section with a few options to change the DC motor speeds. That variables that will be available to the user will be called slow, medium and fast. The variable speeds that were decided are 200, 225, and 255 for slow, medium, and fast respectively. There is section in the application were the user can send commands to the system. These values can be changed to any values between 0 to 255. For advanced users this could be an option, but for normal users this should be restricted. This would allow a safe working system. During tests these values would provide the efficiency the system needs. More information on the testing procedure for these variables can be found on the testing section of this document. This is one of the features that makes the GFC a unique product. These settings are customizable through the application. Open source code for rotating the motor will need to be modified to achieve different speeds. More information on the software implementation of these hardware components will be provided in the Hardware/Module Components section of the Software Design.

8.1.2.4 Instant Motor Activity

From the implementation of different motor speeds, there is a button under the motor speed section of the application that will send a signal to the GFC to instantly show motor activity. This can be accomplished by sending a signal that calls a specific function to test the motor. This feature is added to test the functionality of the motor and that the implementation is working. Similar to the section before the instant motor activity feature does not have a number of testing parameters set. This feature was tested once the hardware assembly of the GFC has been established. Many of the settings mentioned can be debugged using commands that are sent to the system via Bluetooth.

8.1.2.5 Picture Management

The Game Feeder Cam also features a camera system that will take pictures of the environment when sensor readings are detected. These pictures are stored using an SD card that will be connected to the GFC. The application will feature a section that displays the images stored on the GFC. The picture data is transmitted from the GFC to the application via Bluetooth. The picture management section will allow the user to see a preview of the picture, download the picture to their device and remove unwanted pictures from storage. Using Android Studio picture management has been implemented as a gallery based system. This way most mobile operating system users will seem familiar to it.

8.1.2.6 Instant Picture

The instant picture feature is a testing tool alike the instant motor motion. It is used to test the camera system implementation. A button has been placed on the application that the user can use to test the system. When the user presses the instant picture button a signal will be sent to the GFC via the Bluetooth connection. This signal will trigger a function in the GFC camera system that will take a picture and save it to the SD card and display the image to the user in the application. After the picture is taken the application will ask for the picture that was taken and as an option it can instantly display it. This feature can be used to make sure pictures are being taken and stored correctly.

8.1.2.7 Graphical User interface (GUI)

One of the reasons that it was decided to develop an Android application is ease of use for the end user. A GUI or graphical user interface is an essential part of any mobile application. With the GFC we wanted user to use a Game Feeder in a different way. The application will make it easier for the user to customize settings for their preference. This section will discuss how the GUI of the application was implemented and why it was implemented in that way. This section is here to add a bit of extra information to some of the already mentioned implementation, such as motor speeds and picture management.

We will begin talking about the settings menu page of the application. This menu page is intended to be used for customizing many of the features of the GFC and to also provide some information to the user. The selections under this page will be listed below, along with a description of what their use will be:

- Bluetooth Connection – At the top of the settings page it will be displayed what the current status of Bluetooth connectivity is.
- GFC Battery Level – Also at the top of the menu page there will be a current battery remaining on the GFC. This will be used to provide the user with some feedback. This feature should be available to the user in the next update of the application.
- SD Card Storage - The remaining space available and the total size of the SD card will also be displayed below the remaining battery to provide additional information of the GFC. This information can help the user with their decision switching to a new SD card or delete pictures. This feature should be available to the user in the next update of the application.
- Camera Settings – This section will have a few settings that can be about the camera such as picture quality.
- Motor Speeds – The motor speed settings already mentioned previously will be used to change the speed of the servo motor. When the user clicks on this option a popup menu will appear that will let the user select the operating speed of the motor. The available options will be slow, medium, and fast.
- Feeding Times Schedule – The GFC will send out feed two times a day. This setting will be here for the user to select at what two times of the day to send out the feed. This will be implemented using a simple selection of AM and PM times.

The settings page and all of its subsections have been designed using the Android Studio design layout. Activities and menus will be created using these tools. The code from the API is being used to make sure the transitions between the pages are correct and that the correct information will be displayed. The API will make sure that the accurate changes are made within the app one they have been changed on the GFC.

Outside of the settings menu there is a picture management page. This page is here to display the pictures that are stored on the SD card of the GFC. When the user navigates to this section of the application picture information will be requested from the GFC. Displaying this picture information also requires the use of the Android Studio layout design to create a grid based picture gallery where pictures are displayed. A few of the libraries from the Android API will need to be used to display the pictures. Some of the libraries that will need to be used are the App, OS, View, and Widget libraries. Specifically, the Button and ImageView from the Widget library. The SD card interface from the GFC works together with the application so that accessing the pictures can be accomplished. The design of how this will work is based on a communication system between the MCU and the application. The communication system that is being reference uses ready and finished commands that will communicate once picture transfer is finished and ready to send. This would be the ideal case of communication, but for the purposes of implementation the GFC is using a different method. Right now pictures are being retrieved from the SD card, but not automatically. The current system is based on a request and delay. Once a picture is requested the next picture should only be able to be sent once a delay amount has passed. The delay is based on the size of the picture. Receiving pictures this way provide successful testing to implement an automatic system for a future update. While using the picture management section, on the top right of the page there will be a button to activate the live feed feature. This button will only appear if the optional feature was implemented. This feature has not been implemented at the time of this documentation.

This design for a user interface should help users feel comfortable with the product. At this time the implementation of the application has been done. Many of the requirements were met. For functionality the extra features mentioned have not been implemented. These features can be released with future updates. The application used the Android SDK as the main source for the design and programming. The GUI is not yet ready for market release due to many debugging aspects being available to the user.

8.2 Hardware/Module Components

The embedded programming components in this section have been implemented separately first. After making sure that all of the components work individually. Integrating the components to work together was the next step in testing and development.

For this integrated system, there are multiple different components that will need to communicate seamlessly with each other. The key to a smooth implementation and tasks being carried out at the proper time in a trigger system format is in coding the components to communicate effectively with the microcontroller and the Android application. Integration of this system requires that all individual components were correctly coded to perform their intended purpose and relay correct information to the user through the android application. Correct information also needs to be received by the microcontroller. The system was programmed to be activated by different actions, depending on the actions that occurs different actions will be performed. That is what the GFC states were used for. The different states are discussed in the integration section of the paper. For this section, it will be discussed how each of the sections have been programmed and used to find functionality.

8.2.1 Arduino Mega 2560

The Arduino Mega 2560 is programmed using the Arduino IDE software. This microcontroller comes preprogrammed with a bootloader that allows you to upload the code directly to the Mega 2560 unit. Using the IDE to program this microcontroller is very simple and user friendly. The main structure of the code is the setup() function to set the pins and modes and loop() function to perform the main tasks of the sketch. The functions that are used for pin assignments and communication with other sensors and modules are pinMode(), digitalWrite(), digitalRead(), analogReference(), analogRead(), and analogWrite(). The tasks that we are looking to accomplish on this board are organizes as sketches in the Arduino IDE. Once a sketch is chosen, the code for that sketch will appear on the screen. Once we verify this code and make sure the pin choice, baud rate, and other specifics are correct, we choose the verify/compile option and upload the code to the board. All of the testing sketches for the connected modules and sensors and the functionality of the feeder system are accomplished in the Arduino IDE environment. This environment ties the software for all of the individual components together and allows for smooth system integration. The communication between the microcontroller and the components through serial communication is by the built in UART of the microcontroller. The serial communication of these components is accomplished through the sketches operating at the specific component baud rate and we monitor the functionality of these components in the Arduino IDE Serial Monitor.

8.2.2 Bluetooth Module

The connection that needs to be made between the microcontroller and the Bluetooth module is a slave module implementation. In this implementation, a master can communicate with more than one slave but a slave can only communicate with one master. By default, all Android smartphone Bluetooth modules are of master type so we must configure the microcontroller and JY-MCU to connect to the Android Bluetooth module as a slave type. The microcontroller will act as the slave in the network but act as the client in the client to server connection

.

First, an initialization of the temperature control variable in the code will ensure that the temperature control parameters can be monitored. Then, a variable will be declared so a status message of the connection can be reported every chosen amount of seconds for monitoring of the connectivity of the Bluetooth module to the Android device. Once the pins are declared, a setup() section will open the serial connection and open a port. The following loop() section will read user input and output from the device to carry out the user commands. With the user input, a small delay is given and then the input is read and interpreted.

8.2.3 Camera System

The weatherproof TTL serial camera that we are using utilizes the serial ports for communication with the microcontroller unit. The Adafruit library for camera functions can be found on the Adafuit website and this library contains all of the functions that need to be implemented in the camera system. This library needs to be placed in the libraries for the Arduino Mega 2560 for use. There is a simple Comm Tool that can be used to set up serial communication. Using this comm tool, we can initialize the settings of the camera to the ones we will be utilizing. Then, connect the camera to the microcontroller, which has a micro SD card connected for picture storage purposes. By changing the cam.setImageSize(); line, the picture size can be changed and the pin selection can be changed by altering the line NewSoftSerial cameraconnection = NewSoftSerial(x, y); where x and y are the TX and RX pins respectively. When an image has been taken, the image will automatically be loaded onto the SD card and a notification in the Serial Monitor will be given to the user for testing purposes. Figure 28 below shows the camera serial output.

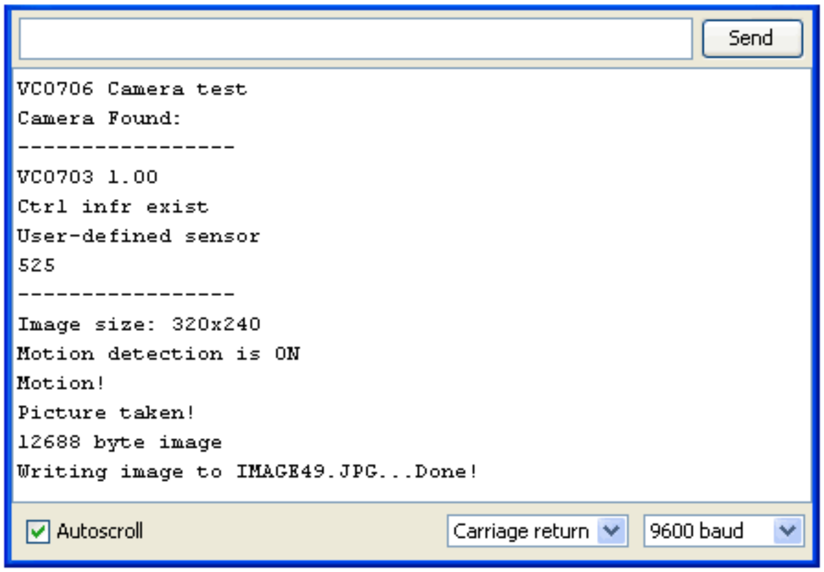


Figure 28 – TTL Camera Serial Output

8.2.4 Servo Motor

The code for controlling the servo motor in the camera system is open source and can be found in the Arduino Lesson 14 Servo Motors. The function that we are implementing in this servo motor is the 'knob' function, tracking the knob's position. This is a very simple code that starts by importing the <servo.h> library of servo motor functions, declaring the variables, and setup() uses the myservo.attach() command to declare the servo pin to the system. The loop() function reads the pos variable to determine the knob's position. The xommand myservo.writeMicroseconds() is used to set the servo motor to the intended angle with 150 being 90 degrees, 1900 being 180 degrees, and 2700 being 270 degrees. This angle measured is then returned as the position of the knob.

The angle that is sent to the servo motor is determined by the four PIR sensor quadrant system shown in Figure 29. When a PIR sensor detects movement, the quadrant of that PIR sensor is determined and the degree of that quadrant is loaded into the servo motor and the knob is moved to that position, effectively moving the camera into the correct position to capture images. The knob position after the images are captured and the tasks have been carried out will return to degree zero (quadrant one).

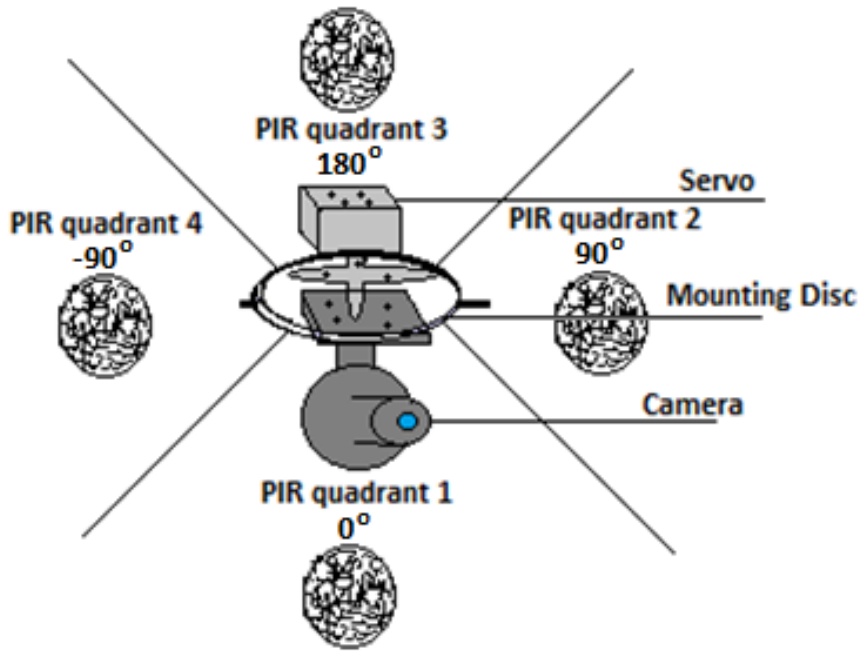


Figure – 29 Quadrant Camera System

8.2.5 DC Motor

Controlling the DC motor responsible for distributing the feed is open source as well and can be found in the Arduino Lesson 13 DC Motors. The DC motor is turned on and off through the pin on the microcontroller. This is used to send a signal to the transistor to turn it on and off, controlling the motor. Controlling the speed of the DC motor is accomplished through a prompt in the Serial Monitor. The code to operate the DC motor is slightly simpler than the code to run the servo motor. After the declaration of the motorPin variable with initialized value, the setup() function initializes the motor to start and prints the command speed 0 to 255 to the Serial Monitor screen. Then, the loop() function is used to take a value of speed from the user and, if that speed falls into the required range, sets the speed of the DC motor and turns it on at the chosen speed.

8.2.6 GSM/GPS Module

The Adafruit FONA 808 GSM and GPS module is relatively straightforward to operate. Much like the camera system, the GSM module library can be found on the Adafruit website and is an open source library. The library is moved to the Arduino Mega libraries for reference in communication between the microcontroller and the GSM module. Testing for functionality in the GSM module is done by using the Serial Monitor at 9600 baud speed. From there you can choose from the options and view the selected information for consistency. With a SIM card the GSM module will connect to the closest available cell tower and can easily send SMS text messages to the Android device's number with a serial command. We will set up this GSM module to automatically send automated SMS messages to the connected Android device with notifications and status changes taking place in the feeder. Figure 31 shows the flow diagram of GSM system functionality.

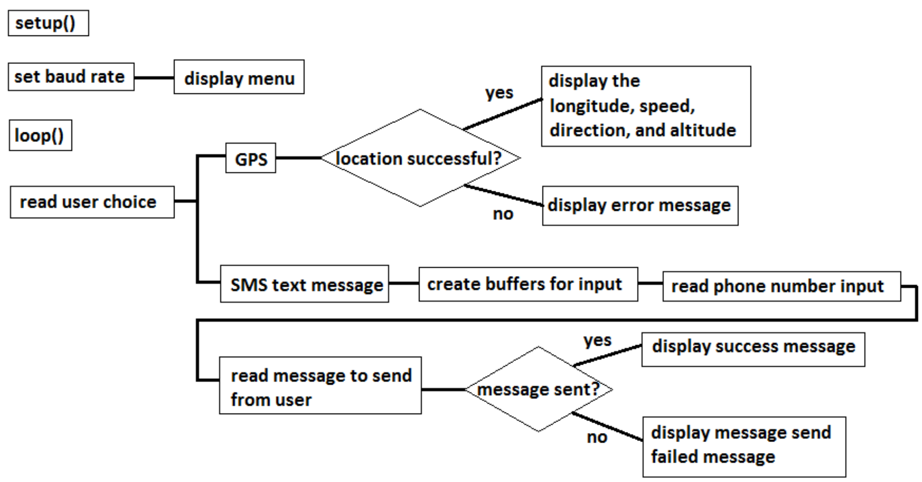


Figure 31 – GSM Text Message and GPS Functionality

8.2.7 PIR Sensors

The coding required for the Panasonic NaPiOn sensors have the one purpose of alerting when the sensor is tripped and motion is detected. The code for these sensors works much like a simple switch. When a sensor is activated, the signal will be given that motion is detected and, depending on which sensor or sensors have been activated, the servo will move the camera to the quadrant associated with that motion sensor. This sensor being tripped sets into motion the task loop of reading the temperature, humidity, barometric pressure, and location, taking a picture, and sending a notification to the user.

8.2.8 Temperature Humidity

The DHT22 temperature and humidity sensor uses an open source code library that can be transferred into the Arduino Mega 2560 libraries. In the library, making sure the correct sensor was declared in the initial define statement, making sure the other sensor versions were commented out, and defining the pin that the sensor is connected to was needed. When the library is in place and the DHTtester sketch is running, the DHT22 sensor can be tested for functionality using the Serial Monitor as shown in Figure 32. The code uses the setup() function to declare the baud rate and initialize the sensor and the loop() function to give a delay then read the output from the sensor, check for errors, compute the heat index, and return the found values. When implemented, this sensor will read the temperature and humidity, giving the third sample taken as the reading to send in the notification to the user.

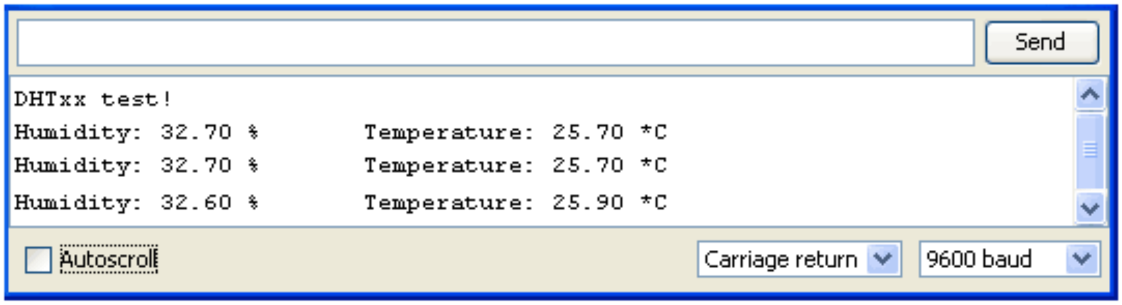


Figure 32 – DHT22 Serial Readout

8.2.9 Barometric Sensor

The open source software library for the BMP180 is available on Adafruit and Sparkfun to add to the Arduino Mega 2560 library in the same way as the other components. Once the library is in place to read the BMP180 data, the Arduino IDE can be used to run a test sketch for functionality before implementation. We will accomplish this task by running the SFE_BMP180_example test sketch with the proper com port selected. Then, once the sketch is properly uploaded to the Arduino unit, the Serial Monitor can be used to read the output of the BMP180 sensor, an example of which is shown in Figure 3. The sketch code uses the setup() function to declare the baud rate and initialize the sensor, giving a failure message if initialization was unsuccessful. The flowing loop() function reads and returns the altitude, reads and returns the temperature, reads and returns the absolute pressure, calculates the relative pressure, and computes the altitude from the pressure, giving an error message with failed readings. Set the Serial Monitor to 9600 baud to communicate with the sensor and the readings will appear in the Serial Monitor window. For implementation of the system, much like the DHT22 sensor, the sensor will read the pressure and the third sample will be taken as the reading to send in the notifications to the user. Figure 33 shows serial output that was tested.

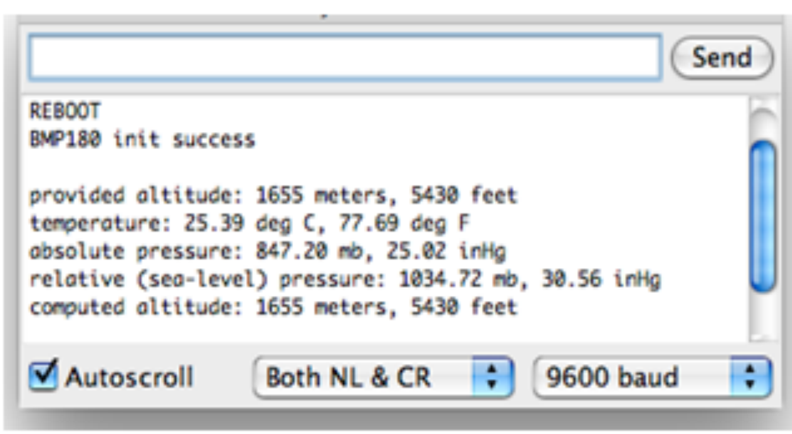


Figure 33 – BMP180 Serial Readout

8.2.10 SD Card

For the SD card to be used with the microcontroller, we first need to format the SD card. Arduino supports both FAT16 and FAT32 filesystems and a formatting tool from sdcard.org is used to easily format the SD card for use. The SD card will be using the SPI mode to interface with the Arduino Mega 2560 because it is much easier for the intended functionality than the SDIO mode. The format for use in the microcontroller is not included, so we had to alter the library to add ‘SD card on any pin’ support so that the SD card will work for the Mega 2560 microcontroller. We accomplished this by changing the if (!SD.begin(chipSelect)) line in the library to if (!SD.begin(x, y, z, t)), where x, y, z, and t are the pins that we will be using for communication with the card. Also, the while (!card.init(SPI_HALF_SPEED, chipSelect)) line must be changed to while (!card.init(SPI_HALF_SPEED, x, y, z, t)) in the same way. In the CardInfo section on code, we also needed to change the chipSelect declaration to the digital pin that we are using. Then, the sketch can be used to initialize and test the card for functionality. We will be using the SD care to store the images that the camera takes until they are transferred to the user’s Android app over Bluetooth at a later time. Figure 34 shows the walkthrough of the code actions in reading and writing to the attached SD card.

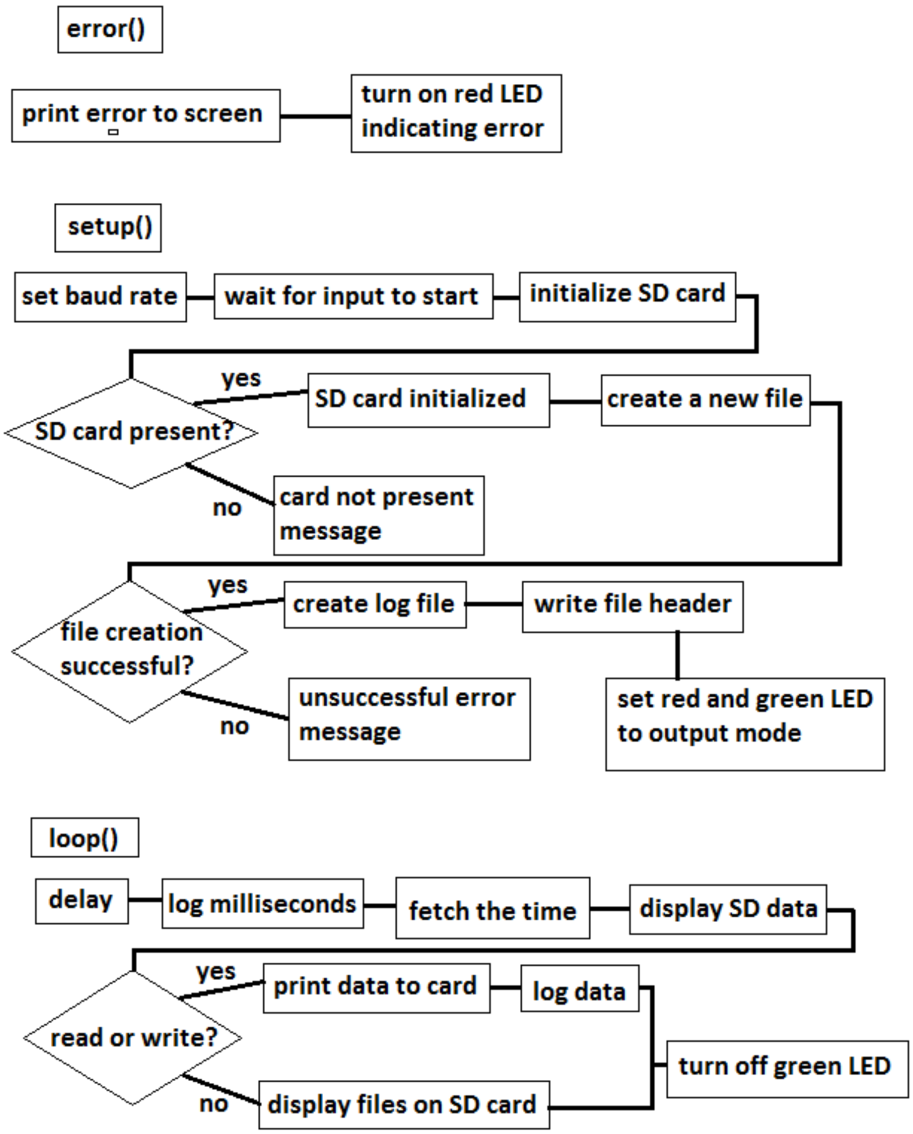


Figure 34 – Reading and Writing to SD Card

8.2.11 SIM Card Service Providers

Most SIM cards come with a voice and/or data plan and can be purchased at most cell phone store locations. AT&T no longer sells a 2G GSM compatible SIM card in the United States and Verizon Wireless and Sprint offer CDMA SIM Cards, but not GSM compatible versions. T-Mobile and Ting are the two service providers that offer SIM cards that can be used in the Adafruit FONA 808 GSM module. Ting plans allow a plan that is just SMS messages and, for one device, would be about fourteen to eighteen dollars a month for access to the network. T-Mobile offers a plan that is pay as you go and three dollars a month for thirty SMS messages with ten cents for each additional text message. This plan would easily surpass Ting in price with the amount of notifications we are sending to the user. Ting is the more cost efficient choice for the GSM module and is also more intended for GSM module functionality. T-Mobile is more intended for cell phones and plans that include network data transmission and minutes for making calls.

8.3 Communications

8.3.1 Bluetooth API

Bluetooth communication using the JY-MCU (HC-06) module requires the importing of the SoftwareSerial library into the Arduino Mega2560 libraries. This allows the sketches and functionality to be referenced by the Arduino IDE and for the microcontroller to communicate with the JY-MCU through the serial pins using the microcontroller's UART, as described in section 7.2.1. The SoftwareSerial library incudes all of the functions required to establish and use this communication. For added functionality if needed hardware serial could also be used for the Bluetooth module.

The SoftwareSerial.begin() function must be called in order to enable the communication. The rxPin parameter is the pin that receives serial data and the txPin parameter is the pin that sends the serial data. The mySerial.available() function takes that data that's already arrived and stored in the serial receive buffer and gets the number of bytes available for reading from the port. The mySerial.begin(baud rate) sets the speed for the serial communication. The function isListening() is used to test and make sure that the serial port is actively listening. The mySerial.overflow() is used to check if a serial buffer overflow has happened and exceeds the 64 byte capacity. This function then clears the overflow tag. The read() and peek() functions return the character that was received on the RX pin. The print() and println() functions print data to the software serial port and transmits this information to the component connected to the selected pin. The mySerial.listen() function enables the serial port to listen and receive data. In calling this function only one port can listen at a time and other data is discarded. The mySerial.write() function prints data to the TX pin as raw bytes and returns the number of bytes that were written. The functions in this library needed to be altered in order to allow communication with more than one serial enabled component at a time. The original functionality of the Software Serial Library only allows for communication with one serial port at a time.

8.3.2 GSM/GPS Implementation

Using the Adafruit FONA 808 GSM and GPS module also requires importing the Adafruit_FONA library into the Arduino Mega 2560 libraries. Much like the Bluetooth module communication described in section 7.3.1, this GSM/GPS module uses serial port communication to communicate with the microcontroller. However, this module requires a separate library for the component functionality.

The library starts by using the begin() function to initialize the module and set the pinMode() and digitalWrite() preferences. The library then attempts to open communication with ATs. Once this is successful, The setBaudrate() function is used to set the speed for communication with the GSM/GPS module. The enableRTC() and readRTC() functions enable and read the values of the Real Time Clock in the form (year, month, date, hour, minute, second). The SIM card must first be unlocked using the unlockSIM() function before use and returns the ID if the SIM using the getSIMCCID() function once unlocked. The Network connectivity is then established and the status is checked using the getNetworkStatus() and getRSSI() functions. After the library accomplished this initialization, only the specific functions for the intended feeder functionality will be used. The only features out of the library that will need to be used are sending SMS text messages for notifications and the GPS. The SMS functionality is first initialized by the library using the getSMSSender() function. The sendSMS() function then sends the text message notification to the given number.

8.3.3 Notifications

During the functioning of the feeder system over time, Alerts will be sent to the user to inform of events of importance occurring. These notifications will be sent to the user by SMS text message to inform the user an action of importance has happened. As described in 7.2.6, these SMS text messages will be compiled and sent through the GSM module with the aid of a SIM card and a wireless data plan.

Motion Sensors: Movement tripping the PIR sensors will set into motion the list of tasks outlined in section 7.2.7. When this chain of events is initiated, we want to inform the user that activity has taken place. It is important that the user knows that the motion sensors are working properly and that the task list is being consistently carried out.

Picture taken: When a picture is taken from the TTL serial camera, a notification will be sent to inform that camera activity has occurred and the number of pictures that have been taken. This will allow the user to confirm that the camera is functioning properly and the number of pictures accurately matches the number of motion sensors tripped.

Storage: A notification will be sent when the user has used up a majority of their SD card storage space. Once the SD card fills up and there is no space left, the pictures that are taken will no longer be able to be stored. It is important that the user must import the pictures and clear the storage space before the available space is used up to ensure that the feeder continues functioning properly. This feature is a tentative addition to the system that was not implemented in the prototype GFC. In future updates to the system, this feature will be added to the project functionality.

Time of Feeding: The user will be informed that the feeder has adequately distributed the corn feed and at what time that occurred. This information is important to ensure that the DC motor and feed distribution is working correctly and hasn't malfunctioned or broken. Also, this ensures that the feed is being distributed at the correct time twice a day without the timing malfunctioning.

Battery Alerts: As the battery gets lower, a notification will be sent to the user when the battery charge is close to being depleted. If the battery power runs out, none of the components or functions of the feeder system will work. This feature is a tentative addition to the system that was not implemented in the prototype GFC. In future updates to the system, this feature will be added to the project functionality. So, it is important to inform the user so that the battery can be replaced or charged before reinstalled. An alert if the battery malfunctions will also be given to the user. Batteries wear out over time and are no longer able to hold a charge and function properly. If this occurs, then the user needs to be informed of this malfunction so the battery can be replaced. This feature has not been implemented with the initial product release.

8.4 Hardware and Software Integration

Now that the Android application and the individual software implementations have been addressed above, a complete integration of how the system operates can be discussed. The Game Feeder Cam can be seen as a procedural and structured system. The GFC will follow a trigger system. Once a particular events occur, that event will trigger a subsequent event. This will keep occurring until a certain event does not happen anymore or the system goes into an idle mode. The GFC has four main states and each will do a particular ask. Each state is explained in the next sections.

8.4.1 Idle State

The GFC operates in an idle state when no events are occurring on the system. The idle state can be considered a low powered state where the GFC will be waiting for an event to happen. The states that can be accessed while the system is idle are:

- The Camera System Cycle
- Feeding Time (Scheduled)
- Bluetooth Connection Established

Each state plays an important role of the GFC. The following states and the events that will be executed at each of them will be discussed in more detail in the next sections. While no activity is detected, the system will remain at the idle stage until the next event is triggered. This implementation allows resources to be used only when they are needed,

8.4.2 Camera System Cycle

We will begin by discussing the main cycle that the GFC will accomplish on a more frequent basis. In its idle state the camera system will be pointing to quadrant one of the system's 360-degree radius. When one of the passive infrared (PIR) sensors detects motion the servo motor will rotate the camera to the quadrant of the sensor that was triggered. The logic for this implementation has not yet been implemented, a series of decision statements will decide the flow of the cycle. In parallel to the camera rotation a timestamp, humidity, temperature, and barometric pressure will be recorded from the GPS module, temperature sensor, and barometric sensor respectively. After the data is collected a picture will be taken. As soon as a picture is taken in this cycle a text notification will be sent to the number programmed for notifications. A delay will be implemented to allow the camera to return to quadrant one. At this point a decision will be made. If another sensor has been triggered the camera system will rotate to the appropriate quadrant of the sensor that was triggered. The entire cycle will then be triggered once again. At the time that no more sensors are triggered the GFC will return back to its idle state. Figure 35 shows a visual representation of the flow in which the events in the camera system cycle will take place.

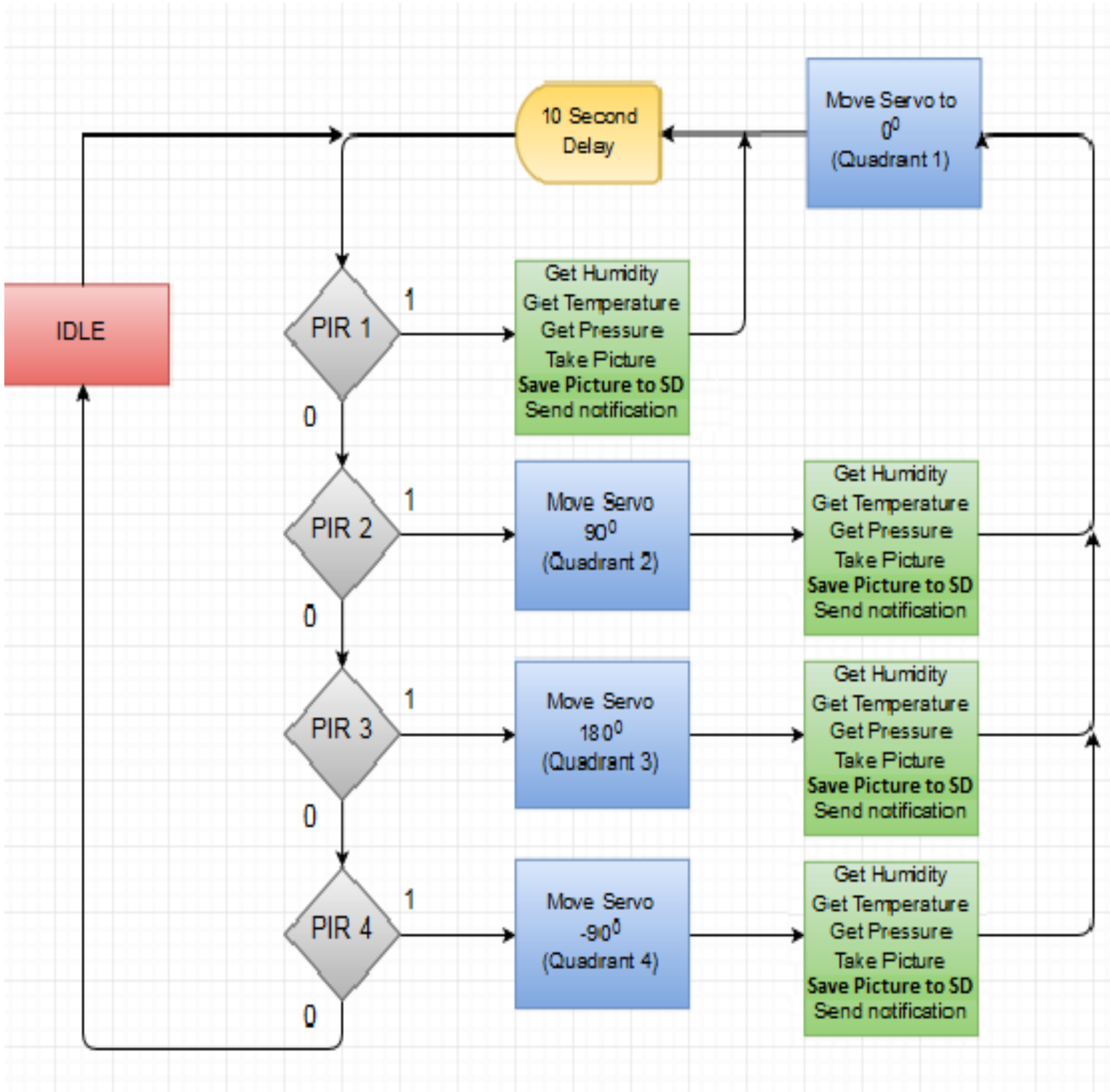


Figure 35 Camera System State Decision Flow Diagram

From figure 35 it is shown the decisions that will need to be made for each even to trigger. We have decided to implement the delay at the end of the cycle to allow the camera to rotate back to the first quadrant and allow for easy calculation for the next quadrant movement. Using this implementation will also allow for one sensor to be triggered at once in a brief period of time. This will save picture space on the SD card and it will also help control the notification system.

8.4.3 Feeding Time

The GFC will have two set times where the system will send out feed. These two times are recorded and set in the system via the Android application. Default values can be used for testing purposes. At the time of feeding the system will enter the Feeding Time state. During this state the GFC will not be allowed to enter the Camera System state or establish a Bluetooth connection. Sensors at this state can be disabled or set to not look for activity. The best implementation will need to be tested before a decision is made on how to control the feeding time state. The events in this state will be automated by the configuration stored in the GFC memory. Once all of the feed for this time has been sent out the system will return to idle.

8.4.4 Bluetooth Connection Established

When GFC is in its idle state Bluetooth connectivity can be established between the GFC and an Android device running the GFC application. While a Bluetooth connection is active the PIR sensors will be disabled to avoid the GFC to continue taking pictures and sending out notifications while the user is in close proximity. In this state the user can fully use the Android application that will be developed for the system. Settings can be customized, picture management can be accessed, and performing tests on the system can be accomplished until a connection is no longer detected. In summary all of the features discussed in the Application implementation will be usable during this event. Using the diagram below we are able to show the sequence of actions that will be taken when a user running the Android application makes a selection. Figure 36 shown below shows a visual representation of the sequence that is followed when commands are sent and received.

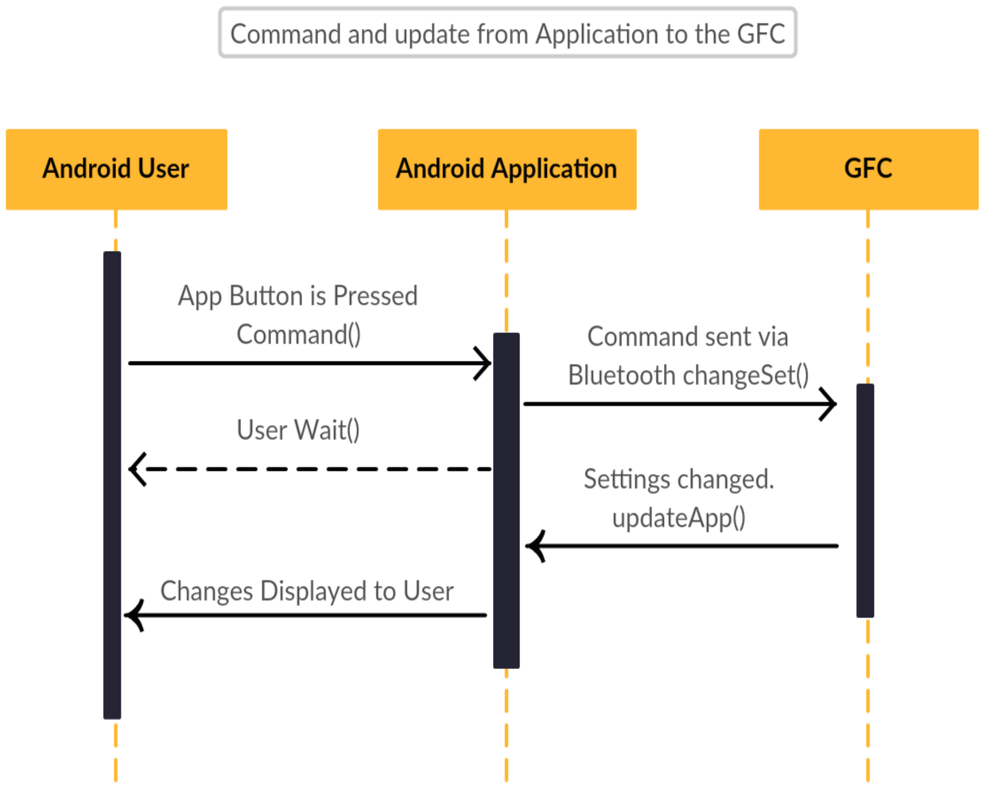


Figure 36 – Command Send and Receive from and to the GFC

For the application and GFC to show updated settings information the GFC and the application need to interact with each other. The above diagram shows that when a command is sent from a device to the GFC, the GFC will update any settings and return feedback to the user. At this point the application will be updated to show that settings have been modified. Once a Bluetooth connection is no longer detected by the GFC the system will return back to the idle state.

8.4.5 Code Implementation

The integration of each of the states explained above has an important role for the implementation of the GFC. Many components will need to work with each other to accomplish a specific goal. Each of the states has a single or more events that will be triggered only during that state. A visual representation of the desired integration for all of the states can be seen in Figure 37.

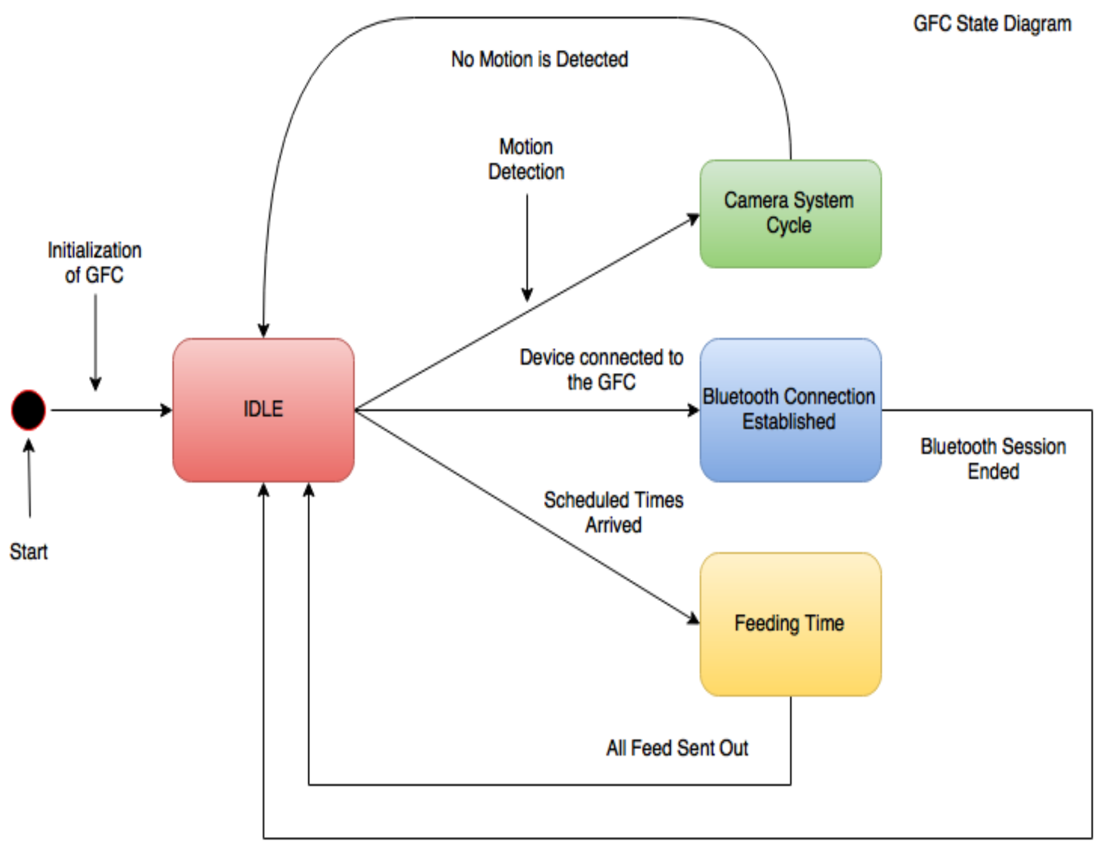


Figure 37 – The GFC Integration States Diagram

In the above diagram we can see the activities that the GFC will be involved in. Please use Figure 35 as a reference for the camera system cycle. The state of the GFC will only change if motion has been detected. Many events within that state will then be executed. At the point that no motion is detected the GFC will then return to its default (IDLE) state. This is to show that from the default state, the GFC will be able to detect different events at the same time.

The code to achieve the desired integration discussed above has not been implemented as of now. Pseudo code was written describing the process of how the code would work. This example code will not be provided. A more detailed explanation will be provided once a working prototype has been achieved. During the integration process of the project, code will be developed for the system components to work together. At the time of integrating this section will include a detailed explanation of how the code was implemented. This section will include some of the testing variables that might and might not work. Finally, it will include a diagram for visual representation.

9.0 Solar Power System Design

In order to get the most out of the captured sunlight and keeping in mind current economic constraints, a polycrystalline solar panel will be used. The solar panel acquired buy the team was donated by the University of Central Florida's electrical engineering department. The idea is to connect the solar panel wish is produces 22V and 50W of power and a current of approximately 5A with the charge controller regulating the amount of power going into the battery. The panel will be connected to the controller and battery using copper 10 AWG 19 strand photovoltaic cable available at amazon for $34.00. Figure 38 below is a diagram representation of the solar charging system.

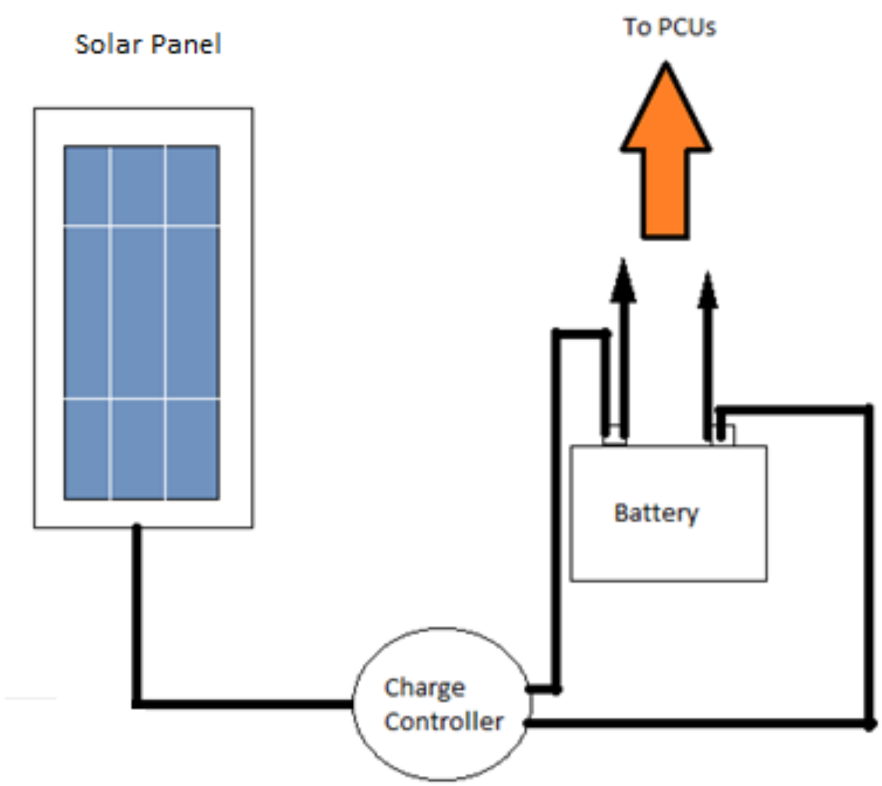


Figure 38 – Solar charging System Schematic

Placement of the solar panel is also critical factor although they come in a somewhat weather proof frame the surrounding wildlife could run into them possible breaking the glass or smaller animals could try to use it as shelter. Thus laying the panels on the ground would not be the optimal placement for the equipment. In addition, placement becomes an issue when attempting to get at most light rays as possible. At the same time, we want the incorporate all of the parts of the feeder system into a single unit that way it would be easier to transport. Therefore, the best way to install the solar panels would be to attach it to the top of the GFC lying flat on a platform. This will ensure a decent amount of sun rays can hit the panels at all times at the same time the panels will be a about 10ft off from the ground which will keep most animals away. The frame of the feeder will have a compartment that will hold the housing for the rest of the power system components. The support arms can be removed and folded behind the panels allowing them to rest on the side of the drum for storage purposes. Figure 39 below shows a diagram of how the panels would look once installed.

Figure 39 - Solar Paneling Placement Diagram

9.1 Charge controller design

As the panel receives sunlight it will send a voltage across the terminal. This voltage fluctuates with weather and environmental conditions therefore to be regulated. There also the potential of getting too much power from sunlight at peak hours this can harm the battery not kept under control.

Out of the charging controller options we decided to build or own lead acid battery solar diversion controller. Granted the short time to create this controller the design of this controller will not be the most efficient of its kind but as long as it will get the job done will be good enough

9.1.1 Diversion Charger Design Schematic

For the solar charger design we decided to build a simple diversion controller with the use of an IC LM723 from Texas Instruments. This circuit is meant to limit the voltage coming from the solar panels into the battery to about 12V. This way it protect the battery from being damaged by overcharging. The voltage regulator triggers whenever the voltage goes above a predetermined value and it enables the NPN transistor (MJ1000) thus the voltage from the solar panel is being grounded and no charge flows to the load. The Regulator does not draw power from battery, except for very low current used for voltage sampling. The zener diode D1 is meant to block current flow from the battery back into the solar panels during night time. Figure 40 below shows schematic for the diversion charge controller along with its final PCB board.

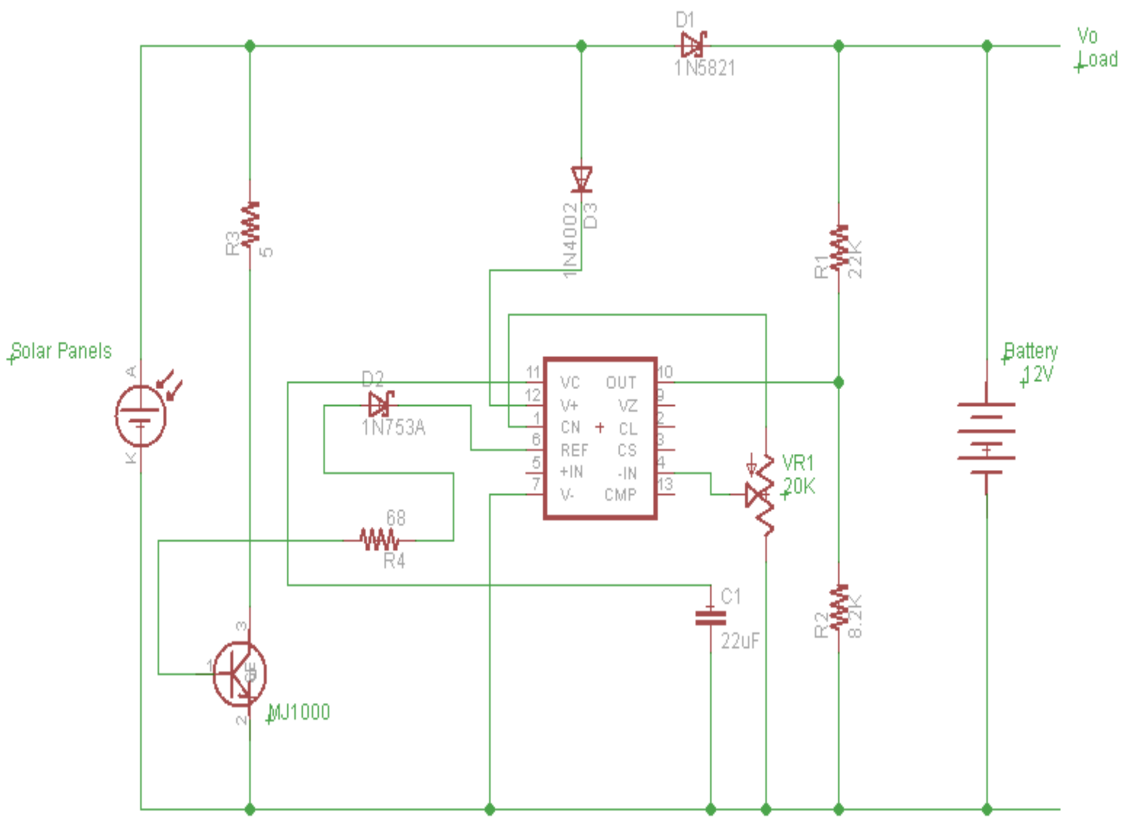


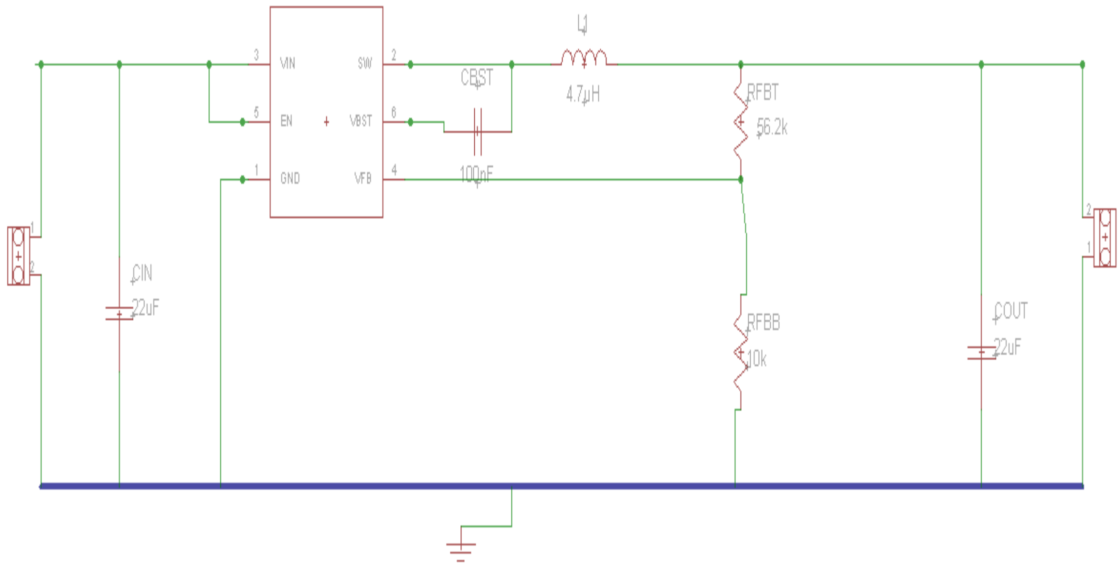
Figure 40 – The Diversion Charge Controller Schematic along with its final PCB board.

9.2 Multiple Power control units

The game feeder system will have multiple power control units they are up to 4 so far. The reason behind this is that if the power circuitry fails at any point in time it will make it more convenient for diagnosing which part malfunction and at the same time I will make easier and more affordable to replace any malfunctioning parts. For example instead of replacing the whole main control board if the camera power breaks down we can just re-order a replacement power control unit of the subsystem itself. The game feeder requires at least four of this power control system each for each sub system. There will be a 5V source for the main control unit board, motion and environmental condition sensors and camera, a 6V for each motor (servo and DC motors) as well as a 3.7V for the GSM module.

Using the assistance of TI Webench power design software we were able to determine all of the voltage regulating control systems that will be used on this project. The Webench program takes in the information of the main power supply and the power requirements from every sub system. Then it find every possible solution and organizes it by efficiency, bill of materials cost, and footprints. After comparing all of the options for the different types of PSU unit designs and efficiencies available considering that there will be a multiple boards inside the power system housing space might become an issue which is why we decided to go with the one of the smallest footprint that still had over 90% efficiency.

First I will discuss the PSU for the main control unit and the camera which is going to be 17V in and 5V 1A out Buck converter that will be connected from the power source from the MCU then the camera will get its power directly from the MCU. Figure 41 bellow shows the schematic for the first power supply unit along with its final PCB board .



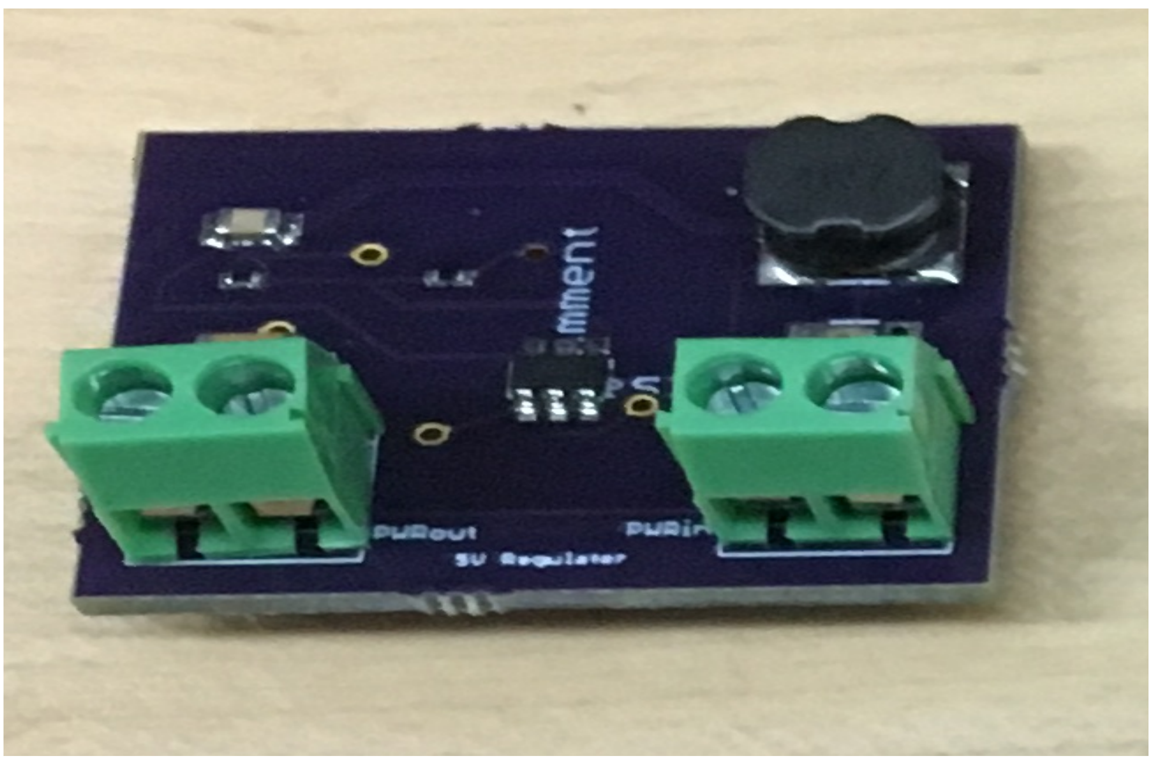


Figure 41 - The First Power Supply Unit Schematic

For the second power supply unit we will use a 1A simple switcher nano module that will convert the 12V from the battery into 6V required for both motors. The switcher will come from the main power source on battery on one side then it will connect to both the servomotor and the feed motors that will be connected in parallel with each other with respect to the switcher. Figure 42 bellow shows the schematic for the second power unit along with its final PCB board.

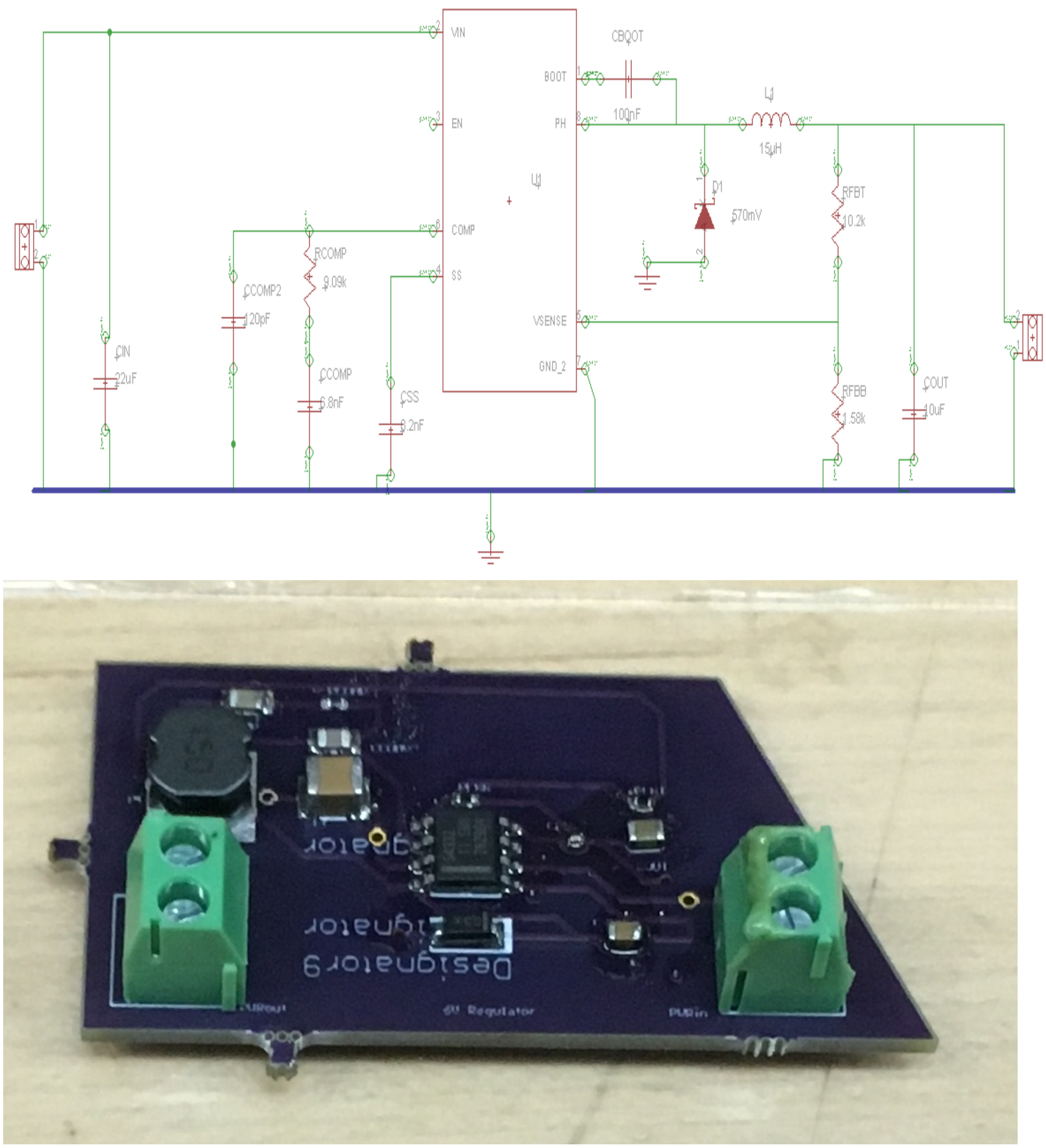
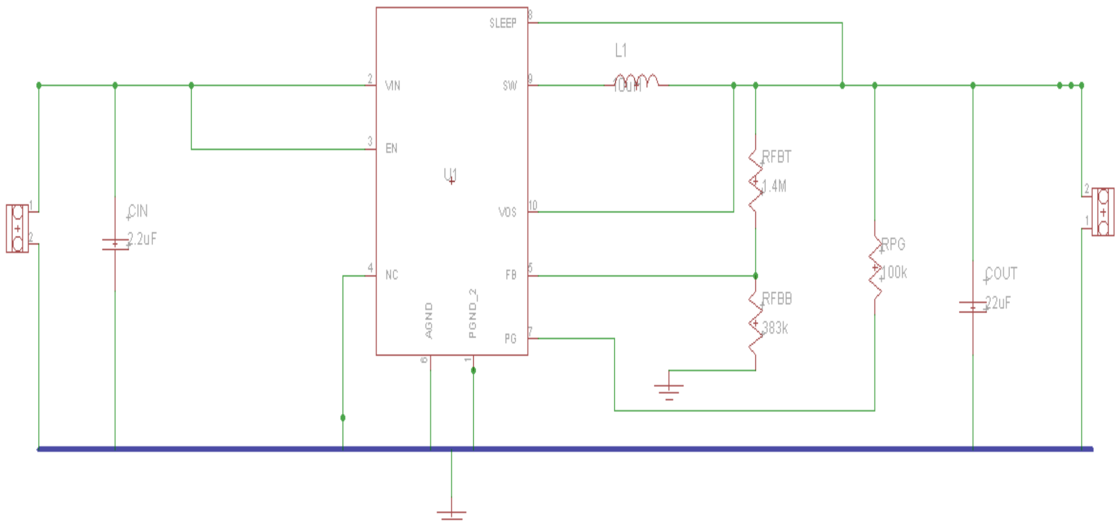


Figure 42 - The Second Power Supply Unit Schematic along with its final PCB board

Finally, for the third power supply unit we will use a high efficiency buck converter that will turn the 12V from the source into 3.7 voltage requires for the communication modules and will also power the sensors that take 3.7V. Figure 43 bellow shows the schematic for the third and final. Figure 6 bellow shows the schematic for the third supply power unit.



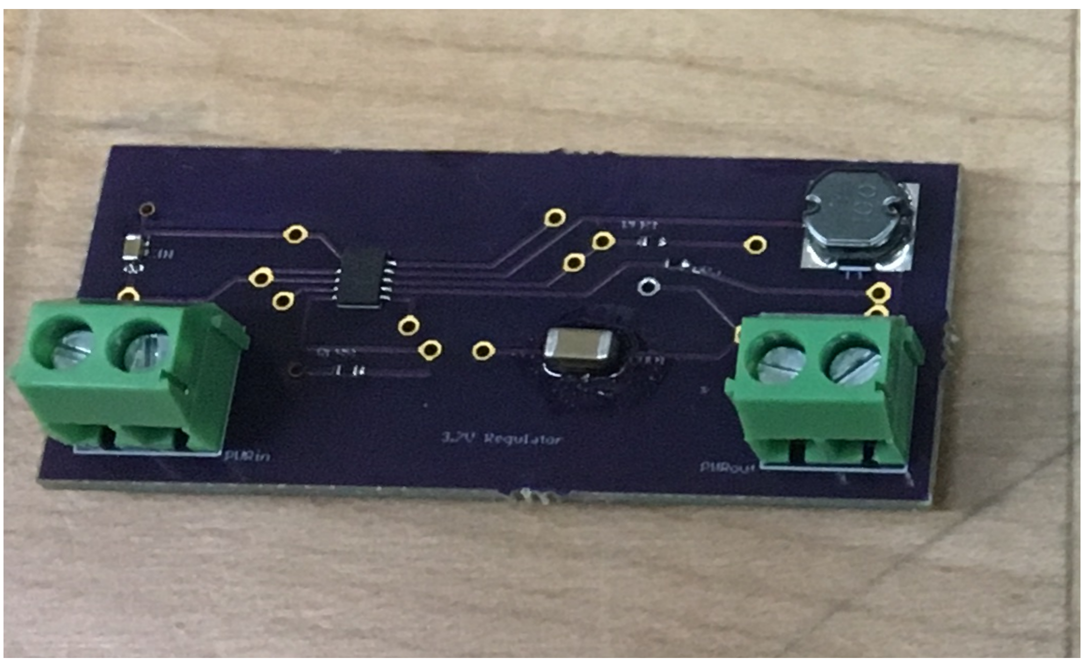


Figure 43 - The Third Power Supply Unit Schematic

Now that we have the complete design schematics for all of the power supply units and determined on how to implement them we can write a more accurate description of the bill of materials. Table 23 shows there bill of materials of the solar power system.

Manufacturer	Seller	Item	Price
Channel Islands Electric	Amazon	Solar cable Copper 10 AWG 19 Strand and connectors	$34.00
Solarland	wholesalesolar	SLP010-12U Silver Poly Solar Panel (x2)	$71.06
Academy Sports	Academy Sports	12V 7 Ah Feeder Battery	$19.99
TI	TI	17- 5V Buck converter with a Power Good	$1.32
TI	TI	1A simple switcher nano module	$2.11
TI	TI	high efficiency buck converter	$1.04
Total			

Table 23 - Solar System Bill of Materials

10.0 Prototyping

Prototyping was conducted as parts were ordered and received. The Arduino Uno was selected first which was not a total loss because it was discovered that the programs would run with pin number modifications on the Arduino Mega2560 which was the MCU that was selected at the end of the semester. Most of the components selected had open source code which was used to prototype, but was modified to integrate into the GFC system as a whole. This prototyping process was important to verify code and component functionality as to not waste time with faulty code or components.

10.1 Motor Control

After laying out the original schematic found on Adafruit Lesson 13 DC Motors and loading the open source code given for the Arduino Uno the six volt DC motor control was tested. This test was done without the feed disc and motor spun at three speeds by changing the PWM values. The motor seemed to lack power so further tests were conducted to determine the problem which led to the DC motor tests being conducted and documented. Because of the initial tests, new components were selected and a motor control board layout was set up to order a final PCB board. After ordering and assembling the final motor control PCB it was found that the N-Channel MOSFET part number IRFP250N would not turn on during every test. Although the data sheet revealed the minimum turn-on voltage was two volts and the maximum turn-on voltage was four volts the five volts the Arduino Mega2560 provided via PWM did not always provide sufficient voltage to turn the MOSFET on. Further research was conducted and a graph on the data sheet for turn-on voltage was discovered revealing a voltage to current graph where at four volts the current was zero. At five volts the current wasn't great enough to turn the motor, a new MOSFET was needed. The MOSFET used in the final design was a FQP30N06L N-channel MOSFET, which was found to be fully compatible with the PWM of the Arduino Mega2560.

10.2 Weather Sensors

The DHT22 and BMP180 were prototyped using both the Arduino Uno and the Arduino Mega2560 without pin modification. Both worked using the given open source code and as expected, the temperature sensor in the DHT22 was more accurate to the actual temperature reading on the thermostat located in the room it was tested. Also found during testing was the need to add additional code to the BMP180 to convert the barometric pressure to the reading provided in a weather forecast inches of mercury. Next the integrated weather sensor PCB layout was tested using a Perf-Board or DOT PCB as seen below in Figure 44 – Weather System Perf-Board Design. In figure 44, there is also a quarter placed on the Perf-Board to illustrate the size, this was important to gauge the actual dimensions of the final PCB for the construction of the weather system housing. A quarter measures approximately one inch in diameter, this allowed the final PCB to be a one by one and a half inch square.

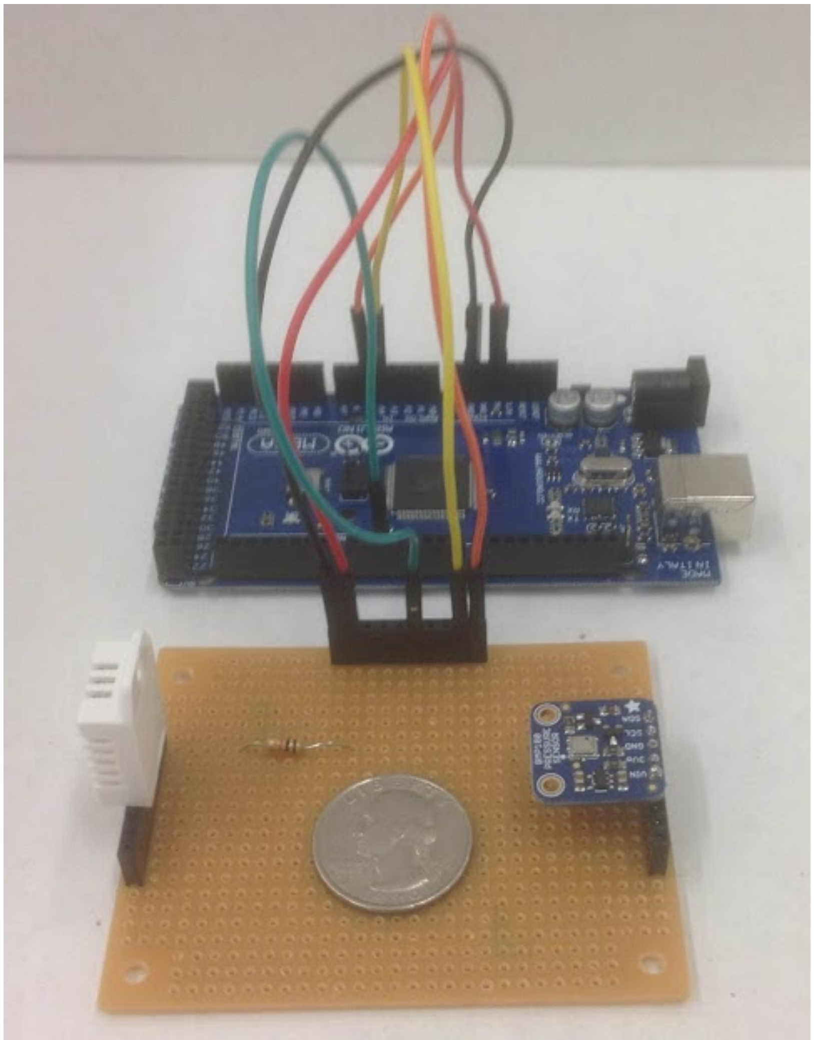


Figure 44 – Weather System Perf-Board Design

10.3 Servo Control

The hitec standard I HS-300 was donated by Keith Kelly for initial servo prototyping. A schematic and open source code was found on Adafruit Lesson 14 Servo Motors to test the donated servo. After initial testing the recommended four hundred seventy microfarad capacitor was added and smoothed out the motion of the servo. The sweeping code was tested and the servo swept from zero to one hundred eighty degrees. Because the camera needs to rotate from zero to two hundred seventy degrees a new servo will need to be selected that will rotate continuously. Also tested was the given servos ability to turn the weight of the camera. To conduct this test the servo was mounted to a board inverted with the acrylic disc and camera attached as seen below in Figure 45 – Integrated Servo Camera Test. The test was run at five volts off of the Arduino Meag2560 using PWM pin 9. The code was altered to allow sweeping from zero degrees to ninety degrees then, ninety degree to one hundred eighty degrees. After one rotation through it was decided the design will fully work after the purchase of a continuous servo. The servo chosen for two hundred seventy degree rotation was the DF Metal Geared 15Kg Standard Servo 270° (DSS-M15S), after testing on the final PCB design it was discovered that the servo drew a full amp in the initial start-up with a load. This was fixed by running a separate five volt step down supply directly to the servo.

Figure 45 – Integrated Servo Camera Test

10.4 PIR Sensor

Initial prototyping of the PIR sensor started with mounting it to a Perf-Board as seen below in Figure 46 – PIR Perf-Board Design. Again a quarter was used to show the size of the actual component and the footprint it will consume on the PCB design. After mounting to the Perf-Board it became clear that in order to flush mount the PIR sensor in the camera system housing the sensor must use a PCB design to allow through-hole soldering. It will also need the three screw terminal to be mounted on the back side of the board to allow a flush mount as well as access to the terminals. After constructing the final camera system housing the above plan for individual PIR PCB's was not used, instead the PIR sensors were silicone directly in their perspective holes and three wires soldered, one to each pin out. When soldering was finished a small piece of heat shrink was fitted over each of the solder joints to prevent any shorts.

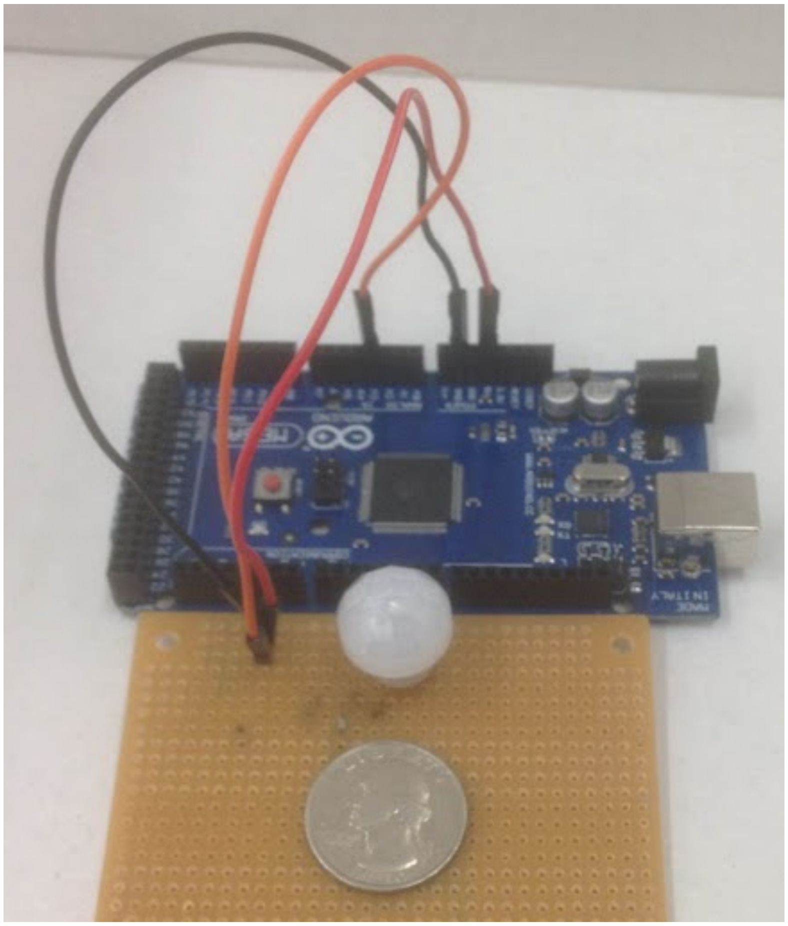


Figure 46 – PIR Perf-Board Design

10.5 Bluetooth Connectivity

Bluetooth connectivity in an essential requirement and feature that the GFC will support. Hence it is crucial that the functionality is tested with great detail to make sure that the other features can be used. Bluetooth connectivity was tested in a couple different ways. The Bluetooth module was tested without any other connections to the MCU. Once new features were coded for example picture transfer, Bluetooth was then again tested to make sure it is working for the desired task. Finally, performance was tested when the complete integration of the system was finished to ensure full system functionality.

To make sure the Bluetooth module works, individual tests were performed. Testing the Bluetooth module consisted of a simple Android application to run debugging tests. This application has been developed to only test for Bluetooth connectivity and making sure that the module can connect and send commands between it and the Android device. This test showed that communication is achieved. This being the first step it was crucial that it worked. Once connectivity was established sample commands were sent to the module to make sure it can execute the commands. Bluetooth continued to be tested for a more advanced feature which for the GFC is picture transfer.

With the help of the Android application that was developed for the GFC, Bluetooth is being used to test all of the communication features of the application. After a working prototype of storage management and picture management have were implemented, the Bluetooth module was tested for more intense data transfer. The API was tested to make sure the code is working properly to send bigger amounts of data. Many errors were found during our tests. Sometimes picture data was not received properly. Many things caused picture data to be lost. One of our test using a faster transfer rate proved to be more efficient since pictures were transferred much faster. The faster data transfer caused bits to not be read correctly. During tests we also found that wrong serial data from the MCU was being written to the picture file before or after the transmission. The Bluetooth API worked as desired, it was other code in the application or running on the MCU that was causing these issues. The following tests were performed to ensure functionality:

- Functionality of the GFC was tested with an Android device communication via Bluetooth with the GFC. Functionality was tested using the Arduino serial monitor using a Bluetooth connection from a laptop. Using this method provided a much faster and easier way to send and receive debugging data.
- Connecting to the GFC while it is in the idle stage – This also tested that the GFC will enter the Bluetooth Connection established state.
- Disconnecting from the GFC – This test was done sending a command to resume the system once a Bluetooth is not desired to be the option.
- Sending, receiving, and executing commands to and from the GFC – This test proved that picture management was possible. Custom settings are also possible using the Android Application or executing direct commands to the system.

Performing these tests made sure that every aspect needed to ensure a working product were met. Once the tests in this section proved to work, it was considered that the GFC Bluetooth functionality was completed.

10.6 Android Application

The Android application that will be used alongside the GFC can still receive further updates to improve functionality and features. Testing criteria has been discussed and implemented with the android application. Since the application was developed using Android Studio, it proves to be compatible with most devices running Android. Devices running Android 4.0.3 (API 15) are compatible with the application. Most Android devices do not share the same hardware, this being the case application functionality was tested on a couple of Android devices. The application was tested mainly on a smartphone. Table are also compatible, but layout issues prove to be different with bigger display devices. Some parts of the application need to be modified to support the tablet audience. Functionality is still there even with large screen devices. The goal of these tests were to ensure functionality not performance. Once all of the features were working on a single device, testing was continued to other devices. Performance testing and optimization started to be tested after functionality. Much improvement can still be achieved if the application is optimized. Once the integration of the system was completed all of the application features were tested. The testing criteria explained in this section only applies to the tests performed on the application. These tests were tested on various devices to make sure it works on different systems. Table 24 provided below explains how the features of the application were tested. Please note that all of these could only be tested after Bluetooth functionality has was achieved.

Application Feature	**Testing Criteria**
Motor Speeds	The motor feature was tested using the interaction activity of the application. Once a user chooses to change the motor speeds, a command will be send to the GFC letting it know to update this setting. The speeds that the motor will support with our integration include values of 200, 225, and 255. These go from slow to fast. These all correspond to a different speed setting supported by the MCU. The variable used could be modified to other values if the right command is sent, but to ensure functionality using the values previously mentioned is desired. To make sure the motor speed has been saved correctly, a motor test is provided for the user.
Instant Motor Activity	Instant motor activity can be used by the developers and the user to make sure the motor is working. This feature also allows the user to see if different motor speeds are being set. This feature will be triggered by pressing a button on the application interface. Once the button is pressed a command will be sent to the GFC to run the motor for a variable amount of time. The variable amount of time is also a customizable setting for debugging purposes and can also be used by the user.

Instant Picture	To test the functionality of the camera a button was placed on the android application. When the user presses this button a command will be sent to the GFC to execute a function that will take a picture at that instant. This picture will only be stored on the SD card and not transferred until asked by the user. This feature is very useful to make sure that the camera and storage systems are working. This feature allows for testing data transfers from and to the GFC. Once a picture is taken, the picture will be displayed to the user in the Android application, the user first needs to initialize a transfer. Then the picture will be shown to then. Once camera functionality was proven to be working the picture management feature was implemented.
Picture Management	Picture management was tested after the storage and transfer implementation were working. There is a section in the application that the user will be able to see the pictures stored on the GFC SD card. The main test is to be able to go to this section of the app and being able to see the preview of each picture. This tests the code that is needed to display the pictures to the user. It also tests the code for data retrieval from the GFC. A series of other tests were performed in this section these include the following: • Viewing the picture in full screen • Exporting/Downloading pictures to the Android device from the GFC (NOTE: This feature has not been tested with picture management. When the user requests a picture from the GFC it is automatically stored in their Android phone.) • Removing unnecessary pictures from the SD Card (NOTE: Removing pictures can be done with the remove file button in the picture transfer activity of the application.)

Table 24 – Application Features and Tests.

After every test in this category were successful, picture management, and SD card storage management were considered to be complete. This will also reinforce that the code for the application is written correctly. Picture transferring and management will require further updates and tests to ensure a smoother experience.

10.7 Hardware and Software Integration

After all of the hardware and software components have been individually tested a full system integration test was performed. The goal of this test is to ensure functionally as an entire project. For the integration of the system a code implementation was programmed. This implementation allows the GFC to enter and exit different states as describe in the sections above. Tests were performed on the GFC to look and test for functionality.

Once the GFC and all of its components are powered on, the GFC starts initialize all components, after the components have initialized it arrives at the idle state. An LED shows the end of initialization. For the user and tester debugging information is via serial communication. This type of checks should only be performed by a tester and advanced users. A Bluetooth connection is recommended for standard users. Once a Bluetooth connection is established interaction can begin.

Since a successful Bluetooth connection is active. Settings can be changed to make sure that the GFC is accepting commands. After the application functionality was tested with the GFC the Bluetooth session was disconnected to ensure the GFC returned to the idle state. The Feeding Time state was also tested, by waiting for the feeding time to arrive. Time was gathered from the GSM module connected to the system. After the time as updated in the MCU, two custom set times for hours were placed. A place holder for the minutes was also added. Once an hour and minute matched it was time for the MCU to enter the feeding state. At this state it was observed that the GFC was sending out food at the appropriate time. This also tested that the feeding mechanism works. After all the feed has been sent out, the GFC returned to the idle state to look for the next time it needs to feed.

The motion sensors were tested next to make sure they are working properly. Once a sensor picks up activity the GFC enters the Camera System state. A series of events are executed at this stage. Once the cycle finishes the cellphone number programmed to the GFC receives a text message indicating that motion was detected and a picture was taken. This is the first criteria that was looked for. After the GFC returns to the idle state a new Bluetooth connection was established. The picture management section of the application can now be tested. A successful event shows the picture that was taken (stored on the SD card), on the application. This was achieved by initiating a transfer sequence from the application to the GFC indicating that a picture can be received.

Since all of the components have been tested. System integration was tested and finalized. Once the integration was tested the Game Feeder Cam was approved as a working product.

11.0 Summary/Conclusion

In conclusion, the overall project utilized a weather system, feed system, camera system, communication system and power system. The weather system and communication system provided the data to stamp on the picture file after the camera system recorded a picture. The communication system also provided text message notifications each time a picture was taken, and allowed wireless mobile application programmability. The feed system provided the bait to lure the animal's close enough to record on camera. All systems were integrated into the MCU where all information and commands are processed. The power system consisting of solar panels, a charging system, a battery and step down units, powered all components. A complete product has satisfied the goals and requirements of the project. The final and main objective of the GFC to have a Feeder System that can be easily customizable with the help of a companion mobile application has been met also.

Appendix A Copyright Permissions

Solar Cell Images:

Permission requests for solar cell images

Permission Request Template

Hello,

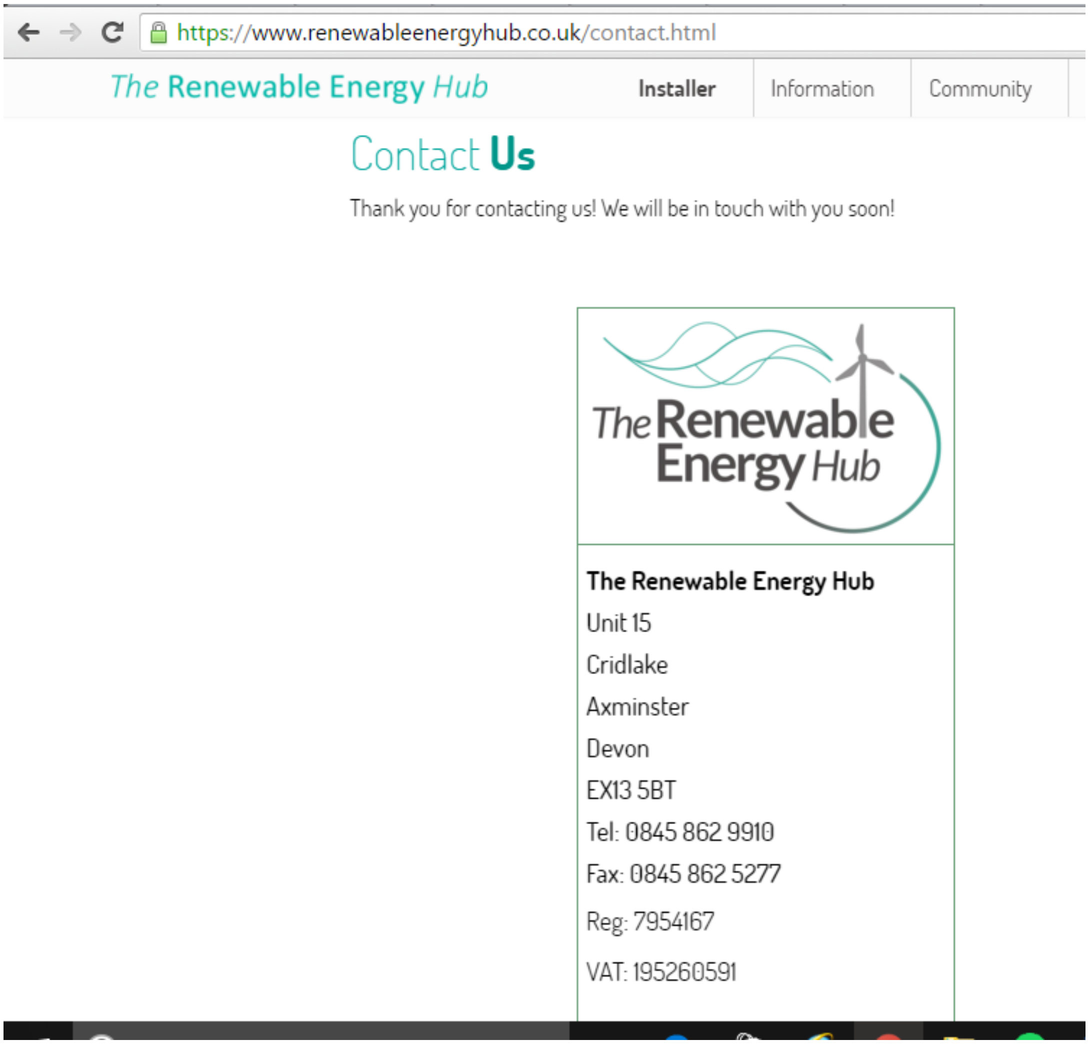
I am a senior engineering student at the University of Central Florida and I am working on my senior design project. I would like to use a picture of the solar cells from your website in my paper and I wanted to ask to make sure it was okay. This paper is for a design class and will not be published or used to make money.

Thank you,

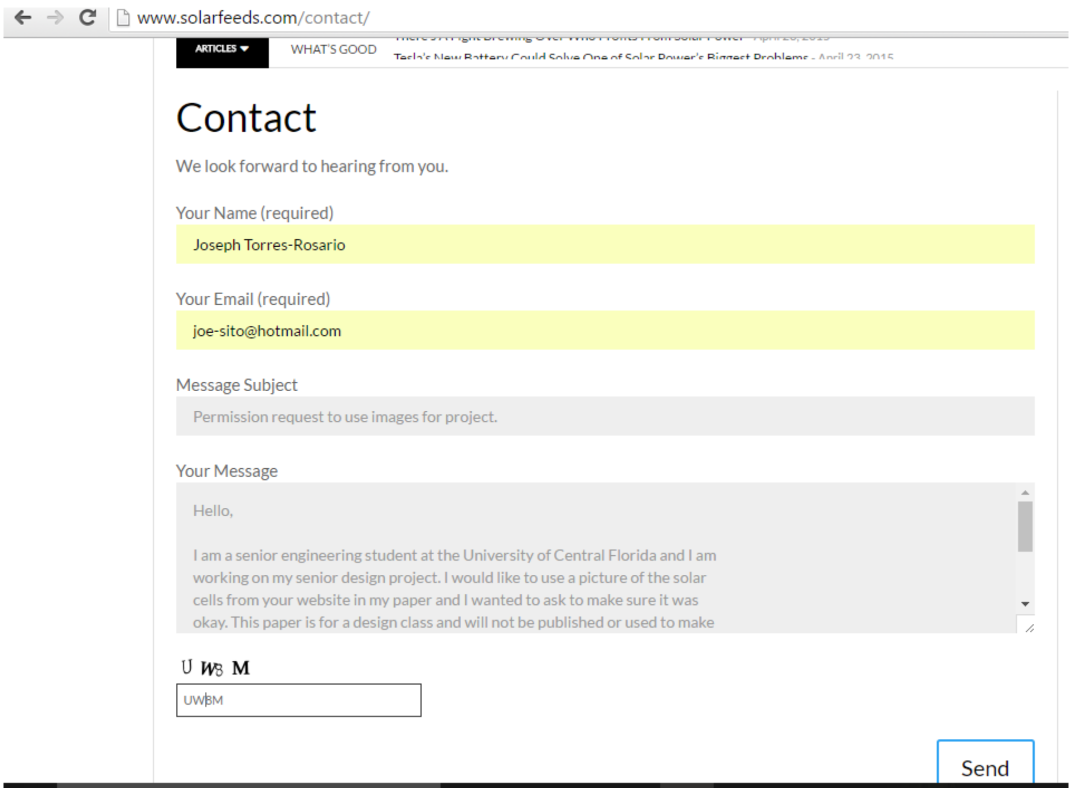
Joseph Torres

Sent from Mail for Windows 10

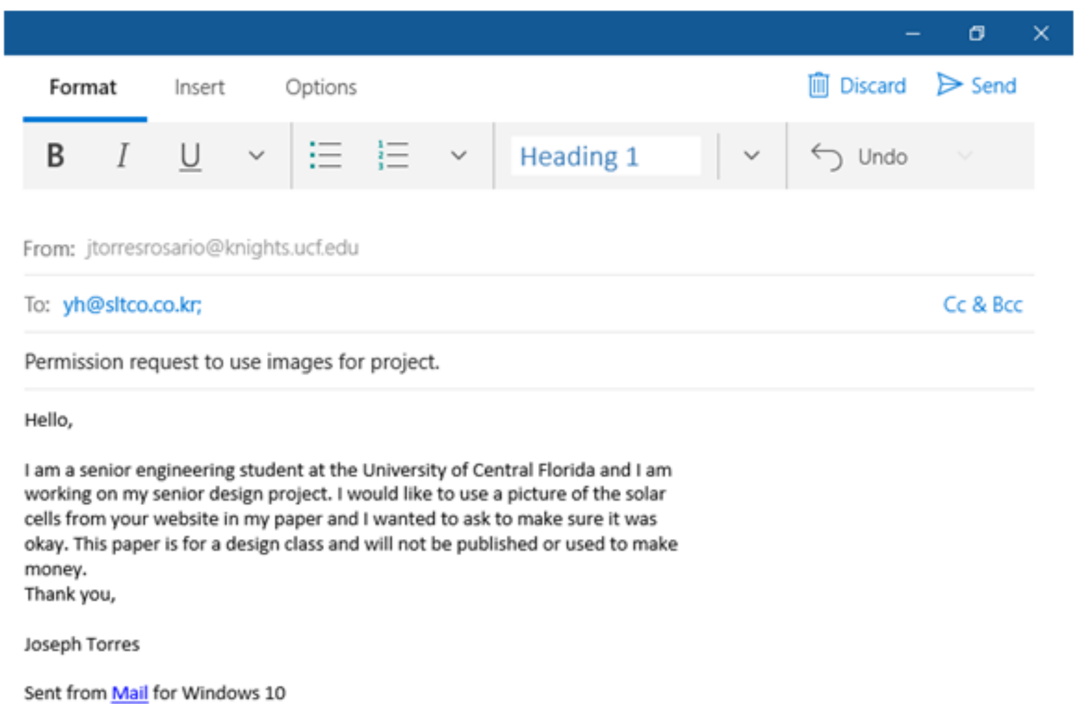
The Renewable Energy Hub:



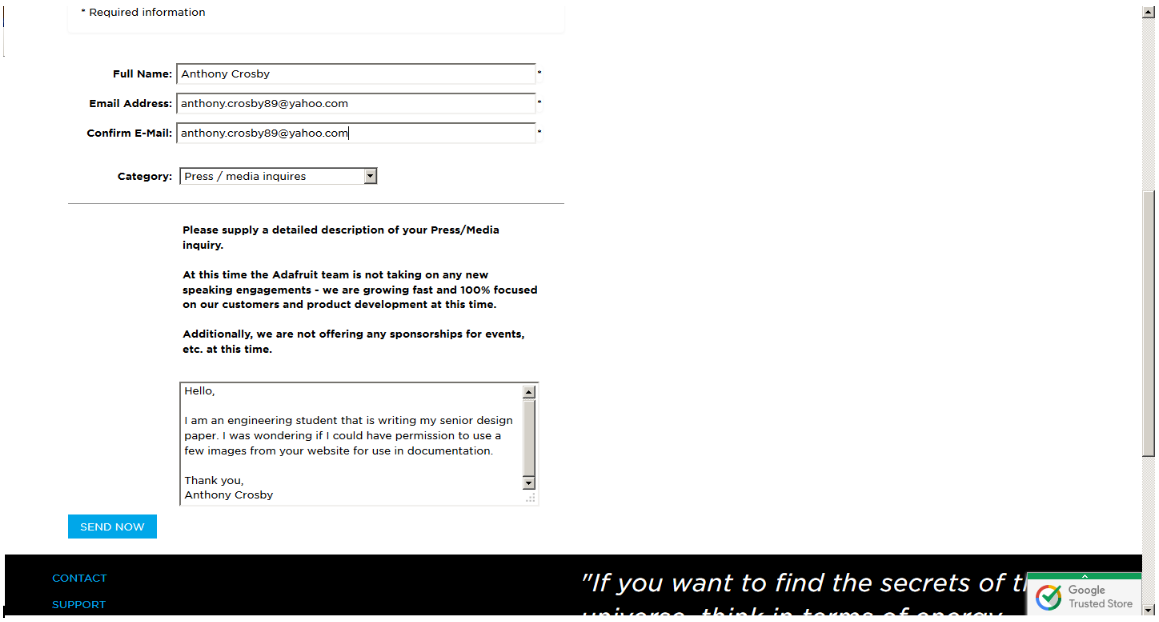
Solar Feeds:



SLT CORP:



Diffen:


* Required information

Full Name: Anthony Crosby *
Email Address: anthony.crosby89@yahoo.com *
Confirm E-Mail: anthony.crosby89@yahoo.com *

Category: Press / media inquires

Please supply a detailed description of your Press/Media inquiry.

At this time the Adafruit team is not taking on any new speaking engagements - we are growing fast and 100% focused on our customers and product development at this time.

Additionally, we are not offering any sponsorships for events, etc. at this time.

Hello,

I am an engineering student that is writing my senior design paper. I was wondering if I could have permission to use a few images from your website for use in documentation.

Thank you,
Anthony Crosby

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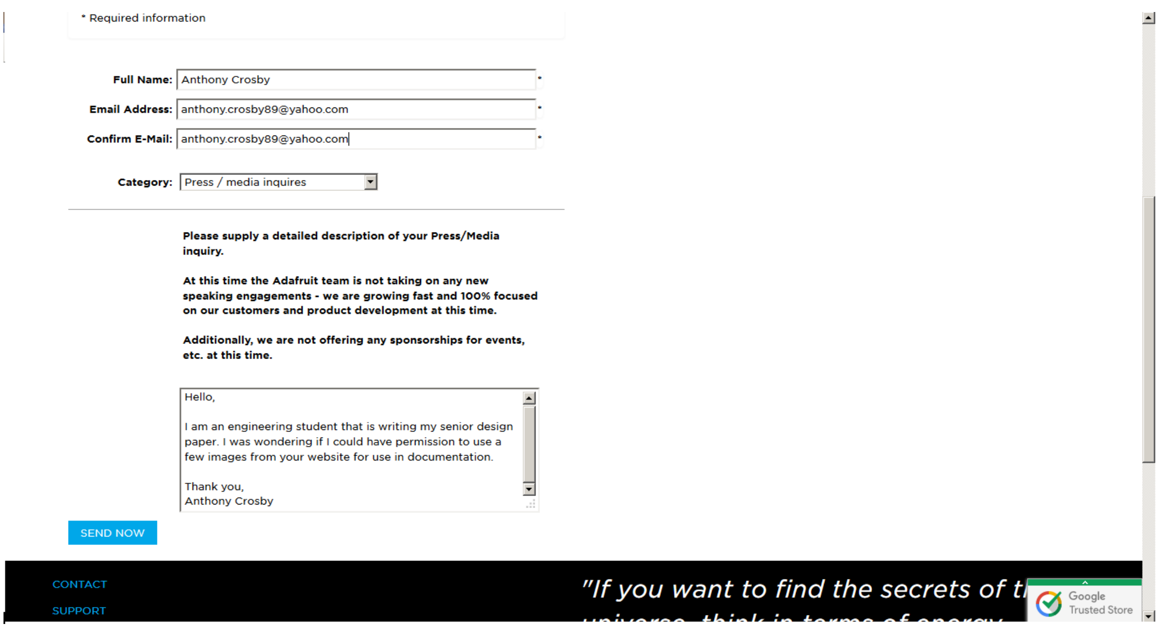
* Required information

Full Name: Anthony Crosby *
Email Address: anthony.crosby89@yahoo.com *
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Thank you,
Anthony Crosby

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SUPPORT

Appendix B Sources

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