Camera Triggering System - ‘PhenoCam’

ECE 445 Design Document

Team 53: Daniel Salazar, Edwin Ortega, Matt Pattermann
Professor: Victoria Shao
TA: Qingyu Li
Spring 2022

1. Introduction

1.1 Problem

As time goes on, climate change keeps leaving its impact. Notably, it affects the development of plants (such as corn). To combat this the Institute for Genomic Biology at UIUC collects data in regards to the plants; such as, height, color, size and so forth. This is crop phenotyping and it is done manually by hand to be analyzed. The team led by John M. Hart has already developed an image processing tool, Computer Vision, to analyze pictures of these crops. The issue comes with the automation of taking the images. The GoPro cameras being used take an image per hour, take images when crops are moving due to wind, or under dark lighting settings. This results in not well taken images which the Computer Vision tool struggles to analyze. In turn, making analysis for the Agricultural Department difficult since the images taken need to be manually filtered out.

1.2 Solution

The solution to this would be a camera triggering system, called PhenoCam, that would be mounted on the rain intercept facility (RIF). This solution would be a GoPro enclosed system that will not be damaged by the weather elements. In order to minimize the number of pictures, it will be able to have variable time-lapse control. Based on the lighting conditions present, the camera will automatically adjust camera parameters (ISO, shutter speed, aperture, etc) in order to maximize image quality based on surrounding conditions. Similarly, images will not be taken at night or when it is dark outside, when the images show nothing analyzable. This is where sensors will come into play and detect wind, rain, and sunlight to adjust accordingly. In reference to wind, to reduce blurry images, the system will delay it's imaging. If possible, it can also interact with the rain facility itself and close the facility if dangerous wind levels are detected. Likewise, under heavy rain the imaging will pause until the rain has stopped. Once the sun starts setting and it becomes dark outside, the camera will stop taking images. The procured images are then uploaded via Wi-Fi to then be analyzed by the Institute for Genomic Biology and Center for Digital Agriculture.

1.3 Visual Aid

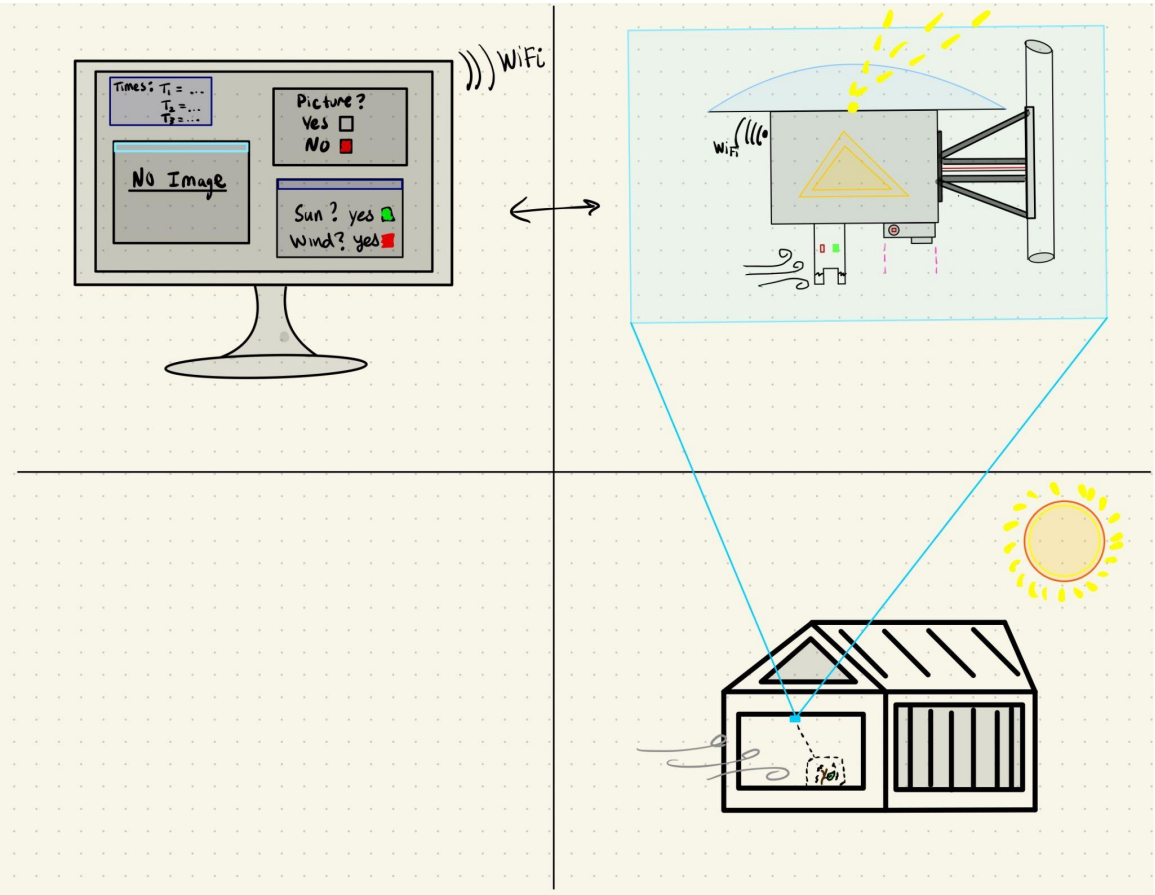


Figure 1 : Visual Aid of 'PhenoCam' System Incorporation

1.4 High-Level Requirements List

- PhenoCam should capture and upload pictures in response to user-specified alarms and environmental conditions.
- User interface should display relevant PhenoCam settings and be capable of remotely controlling PhenoCam.
- PhenoCam should be portable and capable of maintaining battery life for at least 2 days.

2. Design

2.1 Block Diagram

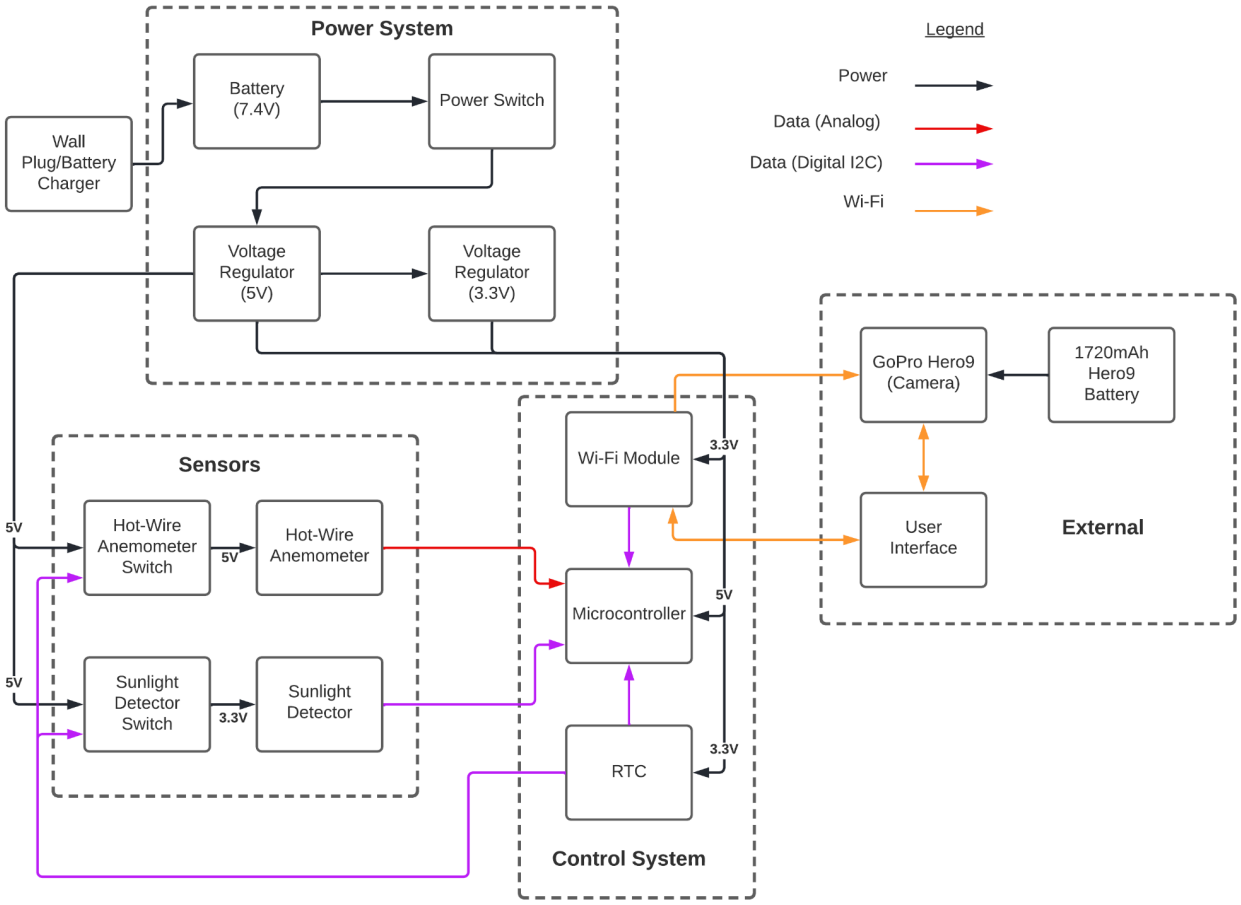


Figure 2 : Block Diagram

The critical subsystems can be split into the following: power system, sensors, control system, and externals. The power system is responsible for providing power to the sensor and control system's at the appropriate voltage defined by individual subsystems. The sensors are responsible for receiving external signals indicative of weather conditions that are sent to the control system. The control system is responsible for interpreting received sensor signals and trigger the camera imaging by sending Wi-Fi signals to the externals. The externals can also send signals to the control system via user interface to change the triggering of the camera.

2.2 Physical Design

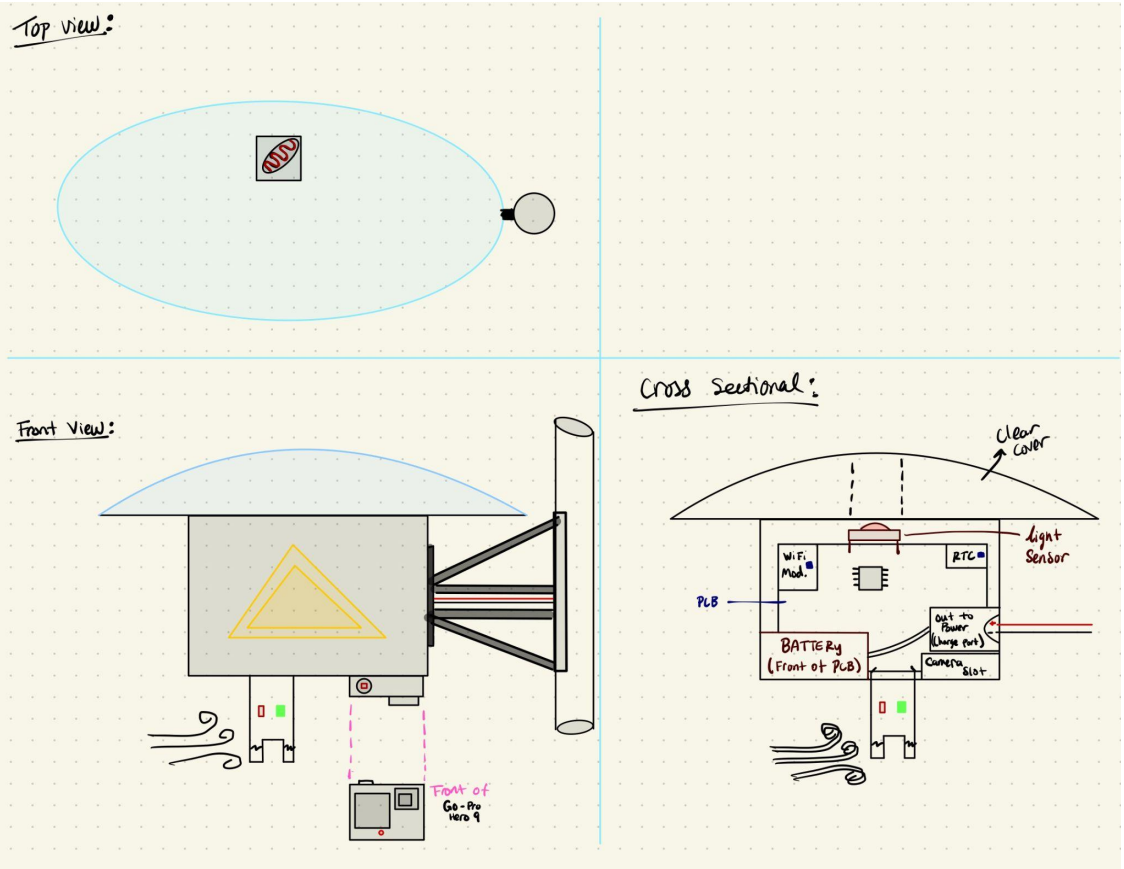


Figure 3 : Physical Design of 'PhenoCam'

Figure 3 shows a set of basic views of the PhenoCam. In the top left image, labeled 'Top View', we see the implementation of a clear hard top that would allow the light sensor to detect the presence of sunlight. The bottom left image labeled 'Front View', shows the overall mounted PhenoCam onto a beam on the facility. The Camera is a Go-Pro Hero 9, mounted facing straight down as this is meant to be approximately 15 feet off the ground. The bottom of the PhenoCam has a hot-wire anemometer sticking out in order to detect flowing wind from any direction. As with the Go-Pro Hero 9, we also expect the anemometer to be detachable from the main housing as this would prevent possible damage of these sensible components when relocating the PhenoCam. The final image present in Figure 3 shows the Cross Section of the PhenoCam. We can see the implementation of a battery within the casing of the device to allow it to function if it is placed in a remote location without access to an outlet. The PCB includes a Wi-Fi module to allow communication with the user interface. There also exists a slot for the removable anemometer in the PCB as well as a light sensor directly integrated into the PCB. In this cross section, we can also see exactly where the Go-Pro mounting slot is located as well as the addition of the RTC directly on the PCB.

2.3 Subsystem Overview

2.3.1 Power Subsystem

Battery

The battery used for this device is a Lithium Polymer with a nominal output voltage of 7.4V and a total capacity of 5200mAh. The battery will be responsible for powering the hot-wire anemometer, sunlight detector, microcontroller, and Wi-Fi module. The chosen battery also is rechargeable to enable longer battery life by allowing charging during non-operational times.

Requirement	Verification
1. Battery must store 5200mAh, with a ~500mAh tolerance, of charge	1. Verification Process for Item 1 a. Attach 5.5Ω resistor as load b. Measure I and V for defined 3-minute intervals using oscilloscope c. Terminate test when $V_{battery}$ is less than 3.7 V d. Perform Riemann summation of collected data points e. Ensure at least 4700mAh extracted
2. Sustain a peak current of 100mA ∓10% during normal use	2. Verification Process for Item 2 a. Attach a 74Ω resistor in series as load with $V_{battery}$ b. Measure I across load using oscilloscope c. Ensure $I_{recorded}$ is at least 90mA or at most 110mA
3. Battery must be unable to discharge if left plugged into charger without power; tolerance of ∓15% of rated 7.4V	3. Verification Process for Item 3 a. Full charge battery using wall plug provided b. Unplug charger from the wall plug c. Allow the battery to sit for minimum 3 days d. Measure $V_{battery}$ using oscilloscope e. Ensure battery has not discharged beyond 15% tolerance

Table 1: Battery R&V

Voltage Regulator Circuit

The RC1616M5T is a linear voltage regulator with maximum voltage input of 7.5V, fixed voltage output of 5V, and maximum output current of 500mA; responsible for providing voltage to the hot-wire anemometer V_{CC} value. The AP7361-33E-13 is a linear voltage regulator with maximum voltage input of 5V, fixed voltage output of 3.3V, and maximum output current of 1A; responsible for providing voltage to sunlight detector, Wi-Fi module, and microcontroller V_{IN} values.

Requirement	Verification
1. 7.5V ∓ 0.2V input voltage regulator has output voltage of 5V ∓ 0.2V at 500mA	1. Verification Process for Item 1 a. Attach a 15Ω resistor load b. Attach oscilloscope across the load c. Supply regulated 7.5V ∓ 0.2V input voltage (DC) d. Ensure output voltage remains betweens 4.8V and 5.2V
2. 5V ∓ 0.2V input voltage regulator has output voltage of 3.3V ∓ 0.2V at 1A	2. Verification Process for Item 2 a. Attach a 5Ω resistor load b. Attach oscilloscope across the load c. Supply regulated 5V ∓ 0.2V input voltage (DC) d. Ensure output voltage remains between 3.1V and 3.5V

Table 2: Voltage Regulator Circuit R&V

Power Switch

The power switch will be the ANT11SF1CQE, which is a through-hole toggle switch.. This ensures that the device does not needlessly waste power while not mounted or while charging. This switch will be directly connected to the battery as well as the voltage regulator.

Requirement	Verification
1. Power switch turns system on (or off) within 3 seconds ∓ 1 second	1. Verification Process for Item 1 a. Connect 7.4V battery to switch in series with 74Ω load b. Attach oscilloscope across the load and switch c. Turn off/on switch and record d. Ensure time is between 2 and 4 seconds

Table 3: Power Switch R&V

2.3.2 Control Subsystem

Microcontroller

The microcontroller device is responsible for receiving analog signals from the hot-wire anemometer and sunlight sensor; as well as, digital signals from the RTC and Wi-Fi module. It is responsible for the ADC operations of the analog sensor signals, as well as the interpretation of the sensor readings. Responsible for triggering the camera in response to both the RTC alarms, as well as delaying these triggers in response to the environmental sensor readings. The ATtiny85 is the selected microcontroller for the I2C serial interface, 6 general purpose I/O lines, minimum 2 8-bit ADCs, and low power consumption in both active and sleep modes.

The microcontroller will interface with the analog sensor(s) through analog I/O pins. It will also interface with digital sensor(s), the RTC, and the WiFi module via digital I/O pins, specifically I2C. Finally, it will receive 5V from the power system.

Requirement	Verification
1. Digital 0 for output of I2C corresponds to $V_{out} \leq 0.3V$	1. Verification Process for Item 1 a. Power controller with 3.3V from voltage regulator b. Upload code setting all digital I2C to LOW c. Probe each pin of ADC output to ensure $V_{out} \leq 0.3V$
2. Digital 1 for output of I2C corresponds to $V_{out} \geq 3V$	2. Verification Process for Item 2 a. Power controller with 3.3V from voltage regulator b. Upload code setting all digital I2C to HIGH c. Probe each pin of ADC output to ensure $V_{out} \geq 3V$
3. Analog 8-bit output ranges from 0 through 255	3. Verification Process for Item 3 a. Power controller with 3.3V from voltage regulator b. Attach analog pins to variable voltage source c. Upload code setting all digital pins to INPUT d. Sweep input voltage and check for proper quantization

Table 4: Microcontroller R&V

RTC

The RTC (or real time clock) is responsible for keeping track of time, specifically in reference to 24 hour time intervals. Additionally responsible for triggering an alarm in calculated time intervals during every cycle of 24 hours in response to user specification. This alarm will send an interrupt signal towards the microcontroller, which will wake it up from low-power mode. The selected RTC is RV-1805-C3, which maintains accuracies within ∓3 minutes per year, communication is done on I2C serial interface (making it compatible with microcontroller), low power consumption of 22nA, and operating voltage of between 1.6V to 3.6V; this operating voltage is achievable due to implemented voltage regulator. Additionally, the RTC contains a super-capacitor for backup power, thus if the battery is not recharged, the RTC can continue functioning.

Requirement	Verification
1. Must be able to operate despite the system's main power system is switched off for 2 hours ∓ 30 minutes	1. Verification Process for Item 1 a. Remove 3.3V power input from RTC b. Connect digital I2C output to microcontroller c. Verify that RTC displays time format in HH:MM:SS d. Record operation time of RTC under no power condition e. Ensure time of operation is at least 1 hour and 30 minutes

Table 5: RTC R&V

Wi-Fi Module

The Wi-Fi module will enable the device to communicate with the server to convey current environmental data, as well as to receive user instructions/specifications. The WiFi will communicate using TCP/IP via WiFi with two clients: the User Interface and the Camera. It will communicate with the device's microcontroller via a direct connection. The chosen Wi-Fi module is a ESP8266 (4MB Flash) which is capable of handling response/write requests, delay of less than 2ms, standby power consumption of 1mW, and requires an input voltage of 3.3V (achievable due to voltage regulator).

Requirement	Verification
1. Standby operation results in power consumption of 1mW ∓ 20% and current of 1μA ∓ 20%	1. Verification Process for Item 1 a. Power module with 3.3V from voltage regulator b. Probe Serial output port 2 of module connected to oscilloscope c. Record I and V for 10 seconds d. Calculate power consumption based on results e. Ensure power is between 0.8mW and 1.2mW f. Ensure current is between 0.8μA and 1.2μA
2. Capable of sending commands over WiFi to the GoPro Hero9 that will trigger the camera to take a photo	2. Verification Process for Item 2 a. Program the ESP8266 with the appropriate WiFi command found in the GoPro Hero Github documentation b. Run the program on the ESP8266 while both it and the GoPro are connected to WiFi c. Check GoPro to see that an image has been taken, either physically or using the GoPro app

Table 6: Wi-Fi Module R&V

2.3.3 Sensor Subsystem

Hot-Wire Anemometer

The hot-wire anemometer will detect and measure the speed of the wind in the surrounding environment. Specifically, we will be utilizing the Wind Sensor Rev C. board produced by Modern Device. The board requires a regulated input voltage of 5V alongside a supply current ranging from 20-40 mA. It is capable of detecting wind speeds ranging from 0-60 mph.

Requirement	Verification
1. Sustain a peak current of 30mA ∓ 10mA under a voltage input of 5V in standard operation	1. Verification Process for Item 1 a. Power anemometer with 5V from voltage regulator b. Probe OUTPUT port to oscilloscope c. Record I of the OUTPUT port for 10 second intervals d. Ensure current is between 20mA and 40mA
2. Sensor must be capable of detecting up to (at minimum) 20mph ∓ 10% wind speeds	2. Verification Process for Item 2 a. Power anemometer with 5V from voltage regulator b. Attach oscilloscope probes to the OUTPUT c. Create a form of wind by placing a fan next to anemometer sensor d. Record the I and V as fan output speed is increased e. Ensure that OUTPUT current and voltage plots decrease in response to increased wind speed f. Analytical calculate a proportion of wind speed of fan to voltage and current recorded to determine mph range of detection

Table 7: Hot-Wire Anemometer R&V

Sunlight Sensor

The sunlight sensor is responsible for detecting the presence of sunlight in order to disable camera triggering under low-light conditions (such as nighttime). The chosen sunlight sensor is LTR-329ALS-01 which operates from 2.4V to 3.6V and outputs in I2C serial interface (compatible with microcontroller).

Requirement	Verification
1. Operates in V_{IN} ranges of 3V ∓ 0.6V	1. Verification Process for Item 1 a. Attach a 300Ω load in series with sensor b. Attach voltmeter to digital output pins c. Apply variable V_{IN} from 2.4V to 3.6V d. Ensure that recorded voltage is within ∓10% of maximum and minimum voltage ratings
2. Digital signal output of 0 for no light is represented by a voltage of $V_{OUT} \leq$ 0.3V	2. Verification Process for Item 2 a. Attach a 300Ω load in series with sensor b. Attach oscilloscope to OUTPUT port of sensor c. Turn off any lights in perimeter d. Record the V_{OUT} e. Ensure the V_{OUT} is at most 0.3V
3. Digital signal output of 1 for no light is represented by a voltage of $V_{OUT} \geq$ 3.3V	3. Verification Process for Item 3 a. Attach a 300Ω load in series with sensor b. Attach oscilloscope to OUTPUT port of sensor c. Turn off any lights in perimeter d. Record the V_{OUT} e. Ensure the V_{OUT} is at least 3.3V

Table 8: Sunlight Sensor R&V

2.3.4 External

Battery Charger

The battery charging will be facilitated by a wall plug/adapter specifically designed for use with lithium polymer batteries. It interfaces with the batteries via the use of an XH-3P 3-pin connector. Recharges at a rate of about 600 mAh.

Requirement	Verification
1. 5200mAh battery is charged within 9 hours ∓ 40 minutes	1. Verification Process for Item 1 a. Connect battery charger to wall plug with 5200mAh battery b. Assume a 9 hour charge time c. Unplug charger and battery d. Perform a battery capacitance test i. Outlined in Table 1 for Battery Verification #1 e. If power extracted is 5200mAh with a 500mAh tolerance, time of charging is sufficient f. If power is not within tolerance, increase charge time and repeat steps (c) - (e) g. Ensure charge time is within 40 minute tolerance of 9 hours

Table 9: Battery Charger R&V

User Interface

The user interface is a web application, accessible from the user's computer of choice, that communicates with the server via Wi-Fi. It will allow for manual input of the number of triggers per time period, view the status of sunlight and wind sensor, and access the snapped images. The user interface will need to interact with the GoPro Hero 9, so incorporation of the GoPro Application would be needed.

Requirement	Verification
1. Allow for a user to specify the desired amount of camera triggers per day and send those specifications to the Control System	1. Verification Process for Item 1 a. Input a desired 10 camera triggers over the course of 30 minutes. b. After 30 minutes have elapsed, review images received by the User Interface and confirm that 30 images total were taken.

	c. Repeat steps a. and b. this time specifying 5 camera triggers.
2. Allow for a user to specify the desired camera settings instead of the Control System, and send these specifications to the camera	2. Verification Process for Item 2 a. Physically check current camera settings, such as ISO, shutter speed, etc. on the GoPro Hero9 b. In User Interface, input values for all camera settings that differ from what the camera currently holds c. Physically check current camera settings, such as ISO, shutter speed, etc. on the GoPro Hero9 to ensure they match the specifications input to the User Interface
3. Display the current camera settings collected and processed by the Control Subsystem	3. Verification Process for Item 3 a. Physically check current camera settings, such as ISO, shutter speed, etc. on the GoPro Hero9 b. In User Interface, review the current camera settings and check whether they match the camera settings recorded from the physical GoPro Hero9.

Table 10: User Interface R&V

Camera (GoPro Hero 9)

The camera chosen by the Department of Agriculture to capture images of crops for study. The other subsystems are designed with this specific camera model in mind for compatibility. As such, there are no requirements necessary for the camera.

2.4 Circuit Schematics

2.4.1 RTC

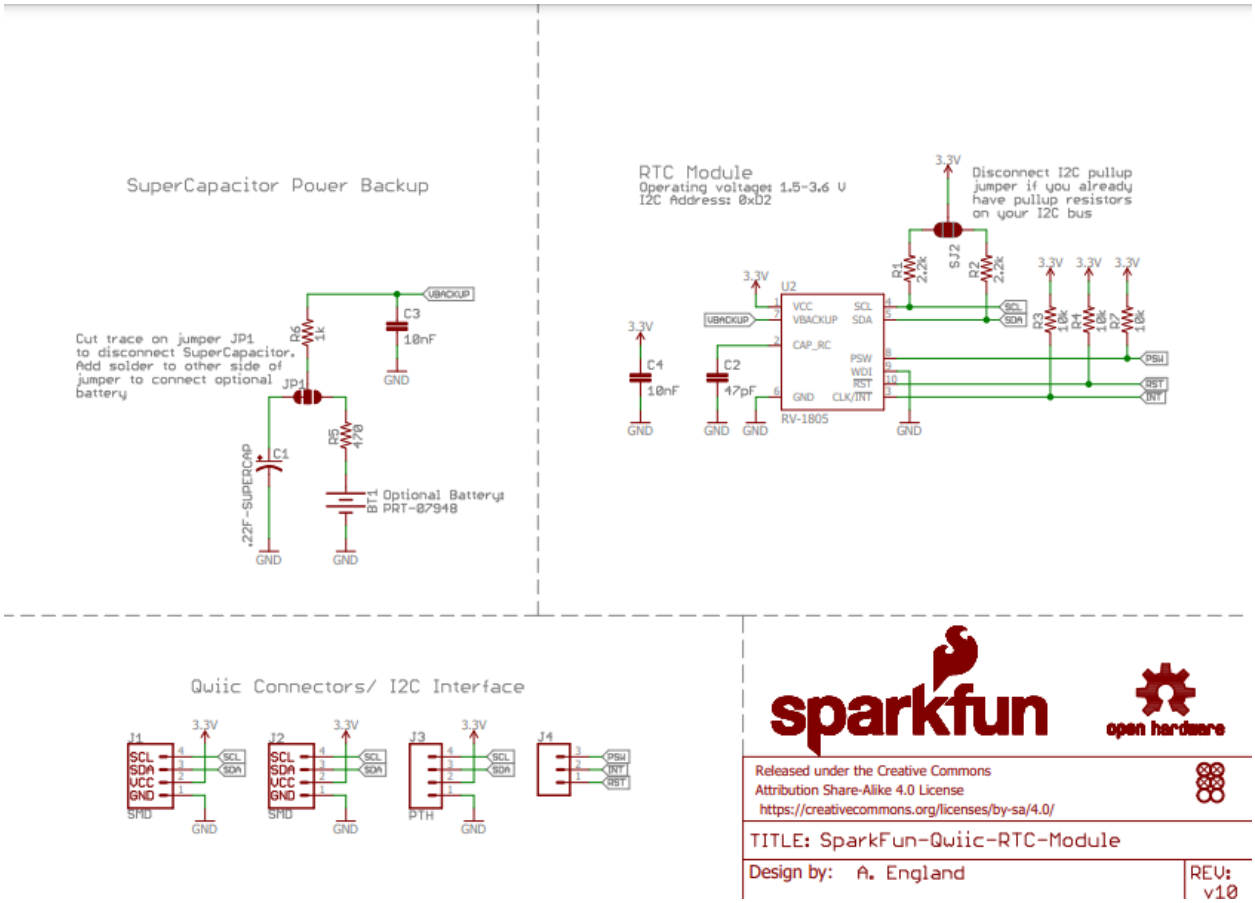


Figure 4: Schematic of Real Time Clock Module as Provided by Sparkfun

2.4.2 Anemometer

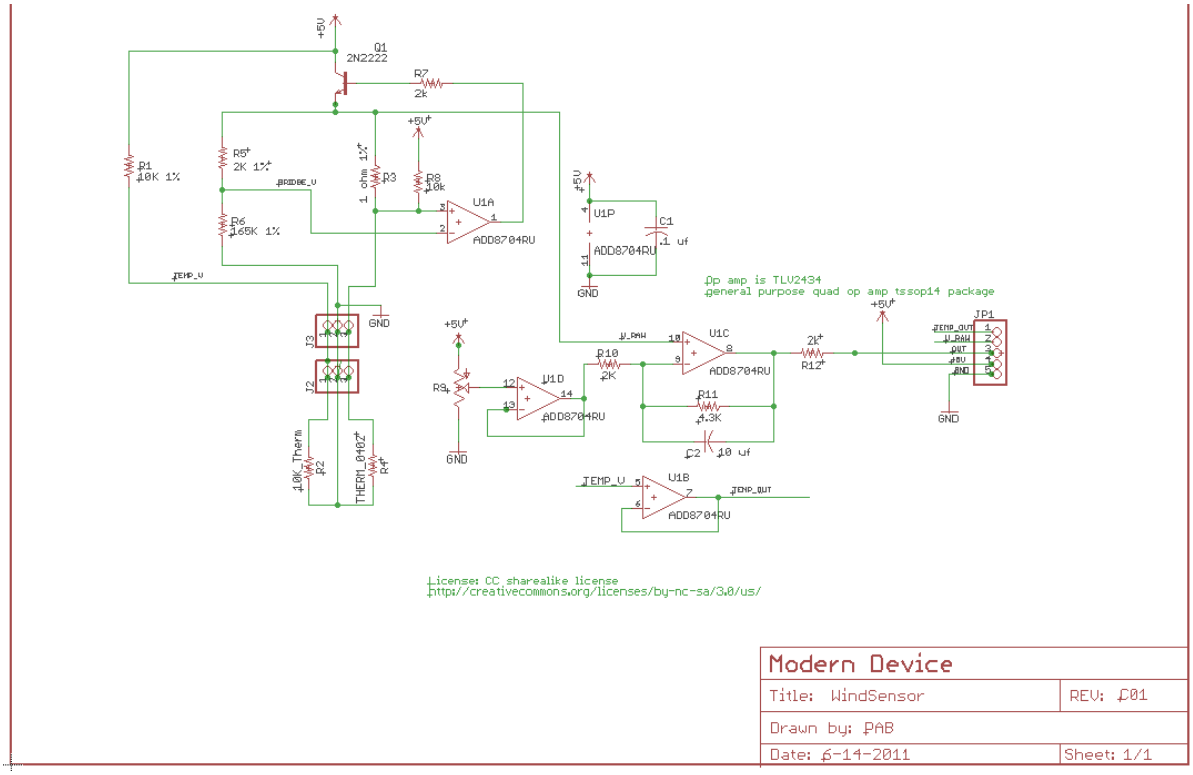


Figure 5: Schematic of Anemometer Module as Provided by ModernDevice

2.4.3 Wi-Fi Module

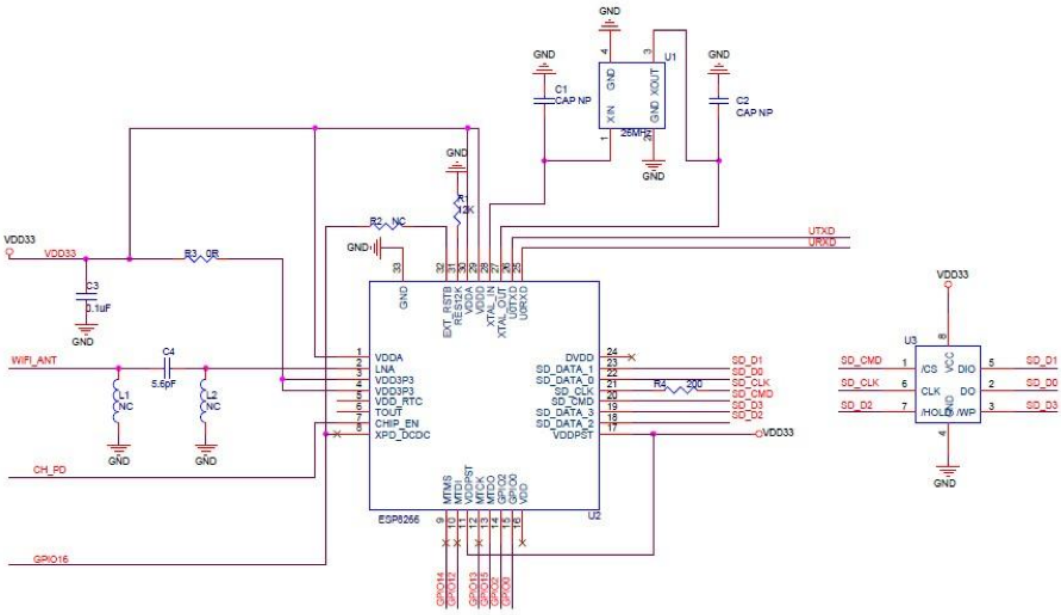


Figure 6: Schematic of WiFi Module as Provided by Sparkfun

2.4.4 Voltage Regulator

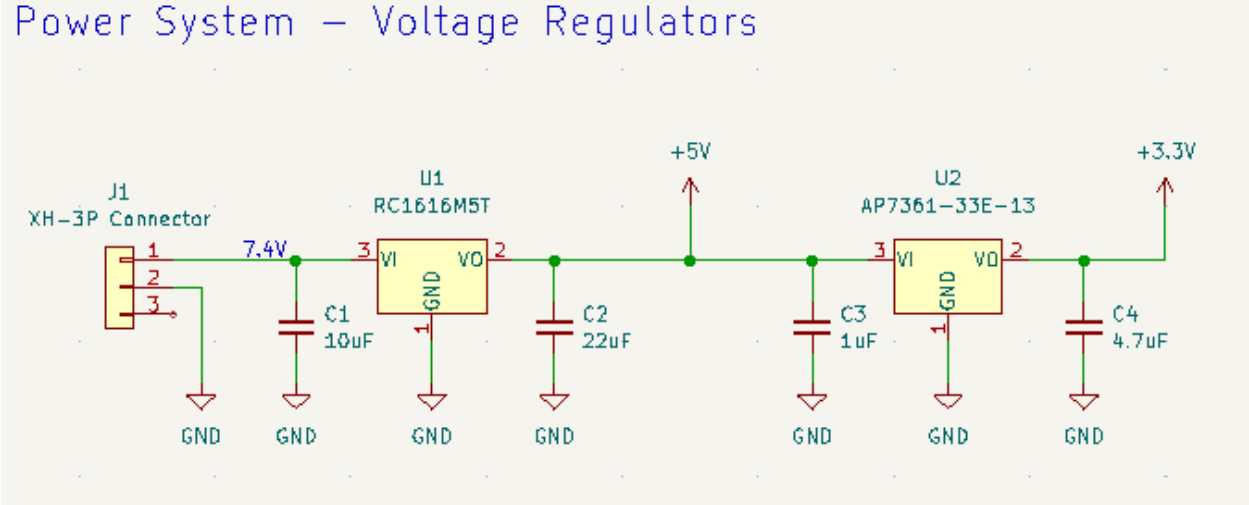


Figure 7: Schematic of Voltage Regulator Module

2.4.5 Sunlight Sensor

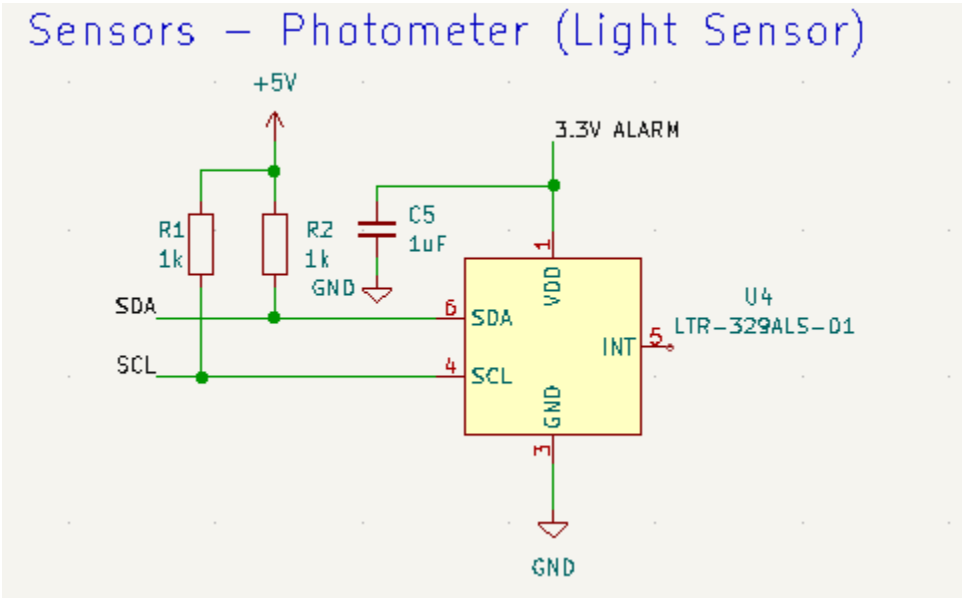


Figure 8: Schematic of Sunlight Sensor Module

2.4.6 Microcontroller

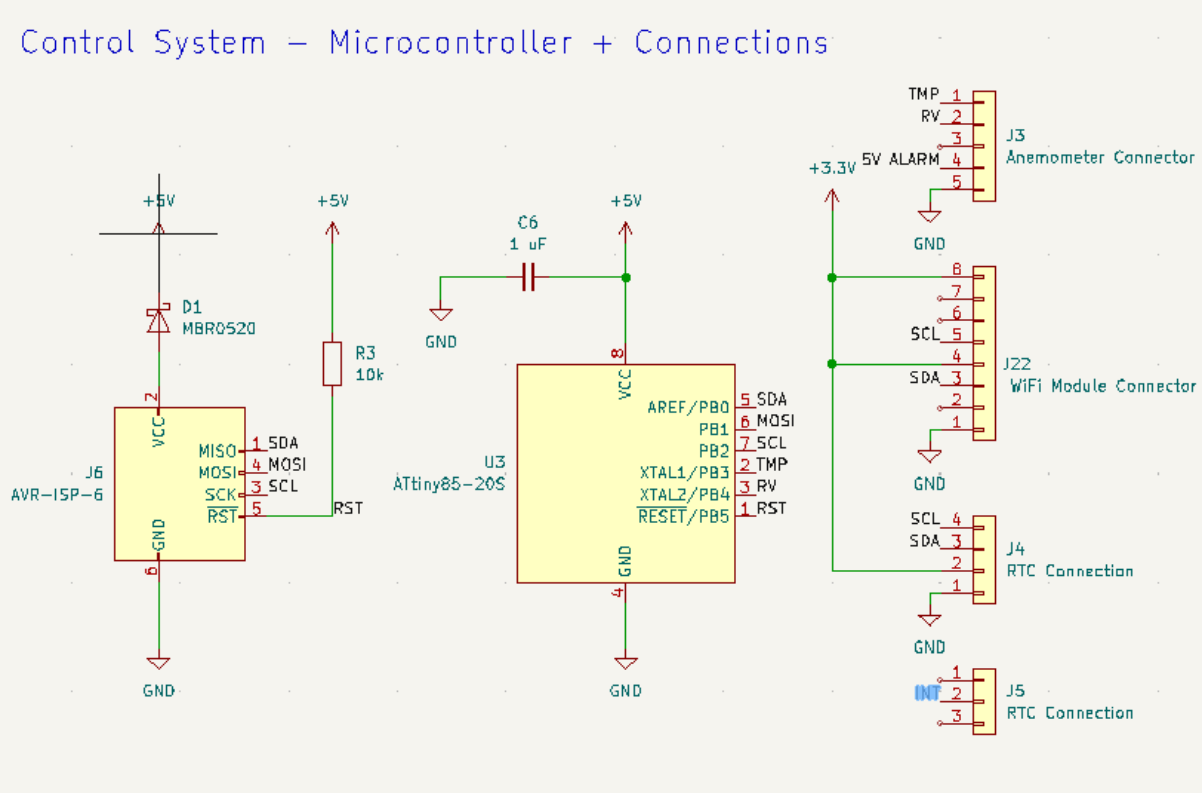


Figure 9: Schematic of Microcontroller Module

2.4.7 Sensor Switches

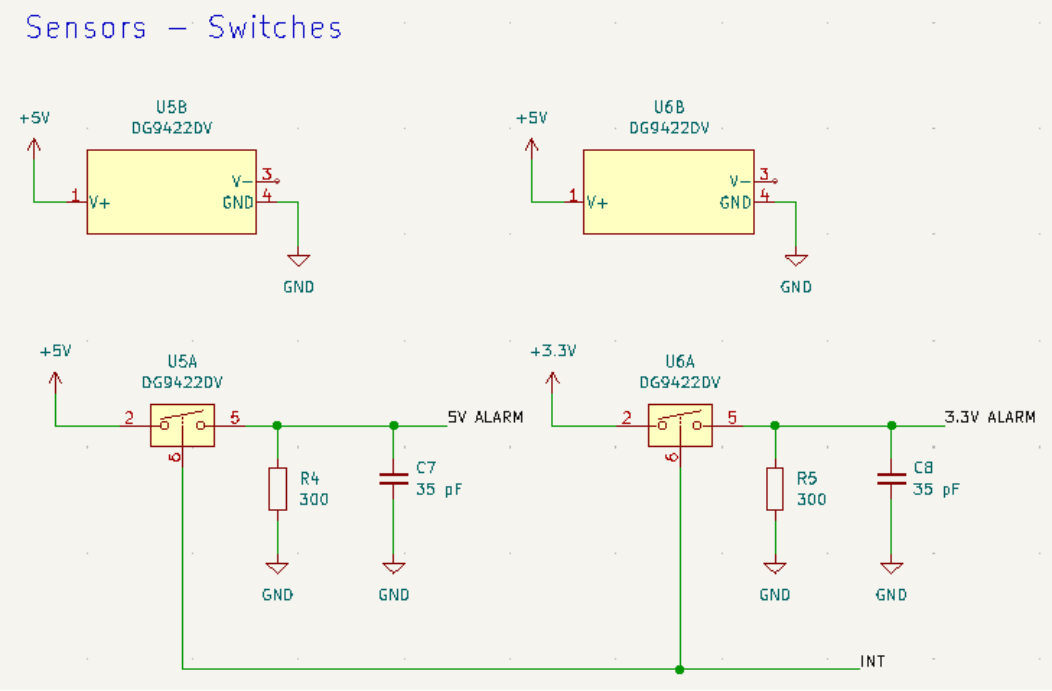


Figure 10: Schematic of Sensor Switches

2.5 Tolerance Analysis

The 'PhenoCam' system is a portable device that is not capable of being directly connected to an AC wall plug for constant power consumption. This means the need for batteries are required. As such, there exists the 7.4V, 5200mAh battery powering the system and 1720mAh rechargeable GoPro Hero9 battery. The system will be operating in either Full On, Interval On, and Standby/Off. Full On corresponds to constant 24hr on-time. Interval On corresponds to 15 minute interval turn on when the image triggering is set to happen. This Interval On is to minimize power consumption and maximize the amount of time the battery can power the system. Standby/Off mode corresponds to the system receiving minimal power due to being turned off. Additionally, the battery life of the GoPro Hero9 itself will be analyzed in order to compare the camera's individual operating time to the system's operating time.

Assuming that we will be taking an average of 4 pictures a day, with an approximate time of 15 minutes per picture, we estimate a rough total of 1 hour ON time. This information will be used for the calculation that will be carried below as in reality, the set number of pictures taken a day depends on what is decided that day and therefore can have a big range.

To determine the run-time in hours, assume 100% efficiency, the equation below would be used:

$$Hours = \frac{C_{Battery}}{I_{total} * V_{CC}}$$

Where the $C_{battery}$ is battery capacitance 38.48Wh or 38,480mWh; determined based on the battery specifications, V_{CC} of 7.4 V, battery capacitance of 5200 mAh. I_{total} is the current total drawn by all subsystems in the entire system.

	Current (mA)	**Current (mA)**	**Current (mA)**	**Current (mA)**				
Mode	Micro-Controller	Wi-Fi Module	Wind Sensor	Sunlight Sensor	**Total Current (mA)**	**Total Power (mW)**	**Total Power at Battery (mWh)**	**Total Runtime (Hours)**
Full On	6e-5	80	30	0.25	~111	821.4	38,480	46.8
Standby Off	1.7e-5	0.0009	0	0.005	~1	7.4	38,480	5,200

Table 11: Battery Life Analysis

To determine the Interval On time, we can proportionally compare to that of the Full On time result of 46.8 hours, rounding this to approximately 2 days of full operational time. Using the switch to power on for determined 15 minute intervals which requires 1 hour of total operation time per day, then the total runtime is approximately 24 times larger due to switching. Thus, interval switching is approximately 48 days of full operational time (or 1,152 hours) with the investment of the switching subsystem. Overall, even on full operation, the system will

operate for nearly 2 days and up to 48 days with approximately 4, 15-minute triggers per day instead.

To be more thorough, Table 12 explores the trigger variability that will be implemented. Since the RIF may decide to take more pictures one day than the other, the triggers might be set to higher values based on their liking. This increases power consumption, reducing effective total runtime. Though even at 16 triggers per day, which is beyond the specified need of the Department of Agriculture, the total run-time is well over 10 days. This reduces the need for detaching the system and replacing/charging the battery.

Since the amount of triggers was predetermined as 4 triggers, despite it being variable, Table 12 shows the different total runtime in hours due to different trigger settings. This is under the same assumption of 15 minute per trigger and that these 15 minutes are equivalent to Full On power consumption

Triggers	**Time Required (Hours)**	**Total Runtime Through Switch Optimization (Hours)**
2	0.5	2246.4
4	1	1152
6	1.5	748.8
8	2	561.6
10	2.5	449.28
12	3	374.4
14	3.5	320.9
16	4	280.8

Table 12: Trigger Based Total-Run Time

3. Cost and Schedule

3.1 Cost Analysis

Within the cost analysis below, tools for testing and verifying requirements are excluded. For example, multimeters, oscilloscopes, banana plugs, probes, etc. since they are used within the scope of the course's laboratory.

3.1.1 Labor

According to the U.S. Bureau of Labor Statistics, the median salary for an Electrical Engineer in the United States is around $103,390; this translates to $49.71 per hour [13]. In order to estimate the team's labor cost, an assumed rate of $40 per hour will be used instead. Assuming each team member commits about 21 hours per week for the remaining 10 weeks to find a total.

Team Member	Hourly Rate	Total Hours	Total Labor Costs	Total Labor Costs x 2.5
Daniel	$40	210	$8,400	$21,000
Edwin	$40	210	$8,400	$21,000
Matt	$40	210	$8,400	$21,000
-	-	-	**Total**	$63,000

Table 13: Labor Cost

3.1.2 Components

Description	Manufacturer	Part #	Quantity	Per Unit Cost	Total Cost
Battery	Powerextra	-	1(2)	$14.99	$14.99
7.5V to 5V Regulator	Fairchild Semiconductor	RC1616M5T	10	$0.20	$2.00
5V to 3.3V Regulator	Diodes Inc.	AP7361-33E-13	10	$0.54	$5.40
Battery Charger	Blomiky	-	1	$15.99	$15.99
Power Switch	CIT Relay and Switch	ANT11SF1CQE	5	$1.69	$8.45
Microcontroller	Microchip	ATtiny85	5	$1.49	$7.45
RTC	SparkFun	RV-1805-C3	1	$18.50	$18.50
Wi-Fi Module	SparkFun	ESP8266	1	$7.50	$7.50
Hot-Wire Anemometer	Modern Device	Rev. C	1	$16.95	$16.95
Sunlight Detector	Lite-On Inc	LTR-329ALS-01	5	$1.06	$5.30
Sensor Switches	Vishay Siliconix	DG9422EDV-T1-GE3	5	$1.80	$9.00
35pF Capacitor	Meritek	MA0805CG350J500	10	$0.02	$0.20
1uF Capacitor	Venkel	C0603Y5V500-104ZNE-CT	10	$0.02	$0.20
4.7uF Capacitor	S.E.M	CL10A475KQ8NNNC	10	$0.10	$1.00
10uF Capacitor	S.E.M	CL21A106KOQNNNE	10	$0.11	$1.10
22uF Capacitor	S.E.M	CL21A226KQCLRNC	10	$0.16	$1.60
1kΩ Resistor	Yageo	RC0201FR-071KL	10	$0.10	$1.00
300Ω Resistor	Yageo	RC0201JR-07300RL	10	$0.10	$1.00
10kΩ Resistor	Stackpole	RMCF0201FT10K0	10	$0.10	$1.00
GoPro Hero9*	-	-	-	$350	-
-	-	-	-	**Total****	**$118.63**

Table 14: Component Cost

**Provided by the Department of Agriculture for use with this project, so cost is not included within component total cost*

***Total cost includes multiple quantities of components in case of loss, damage, or additional testing*

3.1.3 Grand Total

Calculated by combining the labor and component costs. This is an estimated total cost for the entire project. This excludes machine shop quote which will be finalized once the entire project is dimensioned in reference to ordered parts.

Section	Total
Labor	$63,000
Components	$118.63
Grand Total	$63,118.63

Table 15: Grand Total Cost

3.2 Schedule

Week	Daniel	Edwin	Matt
2/21/2022*	Mock Design Doc, Finalize Design Doc, Work on Battery/Voltage Regulator PCB, Pick up GoPro	Mock Design Doc, Finalize Design Doc, Work on Light and Wind Sensor PCB, Order Parts	Mock Design Doc, Finalize Design Doc, Work on Microcontroller/Wi-Fi PCB
2/28/2022*	PCB Board Reviews, Finalize PCB Design	PCB Board Reviews, Finalize PCB Design	PCB Board Reviews, Finalize PCB Design
3/7/2022*	Finalize Machine Shop Design, Teamwork Evaluation, Order 1st PCB	Finalize Machine Shop Design, Teamwork Evaluation, Research Programming Commands for GoPro	Finalize Machine Shop Design, Teamwork Evaluation, Research Microcontroller Interaction with GoPro
3/14/2022	Spring Break	Spring Break	Spring Break
3/21/2022*	Assemble PCB for Testing	Write Code for GoPro and Microcontroller	Write Code for GoPro and Microcontroller, Order 2nd PCB
3/28/2022*	Individual Progress Report, Test Design and Take Measurements, Refine Code	Individual Progress Report, Test Design and Take Measurements, Refine Code	Individual Progress Report, Test Design and Take Measurements, Refine Code
4/4/2022*	Test Interaction of User Interface and Project, Assemble PCB 2 for Testing	Test Interaction of User Interface and Project, Refine Code	Test Interaction of User Interface and Project, Refine Code
4/11/2022**	Prepare Project for Mock Demonstration, Test Iteration #2	Prepare Project for Mock Demonstration, Test Iteration #2	Prepare Project for Mock Demonstration, Test Iteration #2
4/18/2022	Mock Demonstration, Improve Demonstration for Final	Mock Demonstration, Improve Demonstration for Final	Mock Demonstration, Improve Demonstration for Final
4/25/2022	Demonstration, Mock Presentation, Write Final Report	Demonstration, Mock Presentation, Write Final Report	Demonstration, Mock Presentation, Write Final Report
5/2/2022	Finalize Final Report, Final Presentation	Finalize Final Report, Final Presentation	Finalize Final Report, Final Presentation

** indicates weekly communication with John M. Hart regarding the status of the project; this is either a Zoom meeting or email*

*** indicates the expected deadline to demonstrate the project with the RIF along with John M. Hart to show progress. Deadline created by RIF since that is when planting of crops begins*

Table 16: Schedule from Week 6 to 16

4. Ethics and Safety

The ethical aspect of this project is mainly in regards to how safely we can implement the project. In reference to IEEE's code of conduct, Section 1.1 States "we must hold safety, health and the welfare of the public as our top priority, as well as strive for an ethical design and sustainable development practices, and disclose factors that might endanger the public or the environment".

One of the main concerns surrounding our project is the fact that we will be implementing a circuit to an area that is exposed to water/rain. Of course, as we know electricity and water do not mix, so it is our goal to try and make our project housing water resistant to avoid any type of short circuiting. This proves to be a challenge as we need to implement sensors that will need to be exposed to the elements to accomplish their tasks, and will make it difficult to make the casing entirely water resistant. This is ideal for the safety of whoever accesses the rain facility and the facility itself.

In addition to the proximity of electricity and water, we must also consider another possible hazard. Since we are to mount our project to a rod in the rain facility, we must ensure that it is properly mounted to avoid injury from a falling object and prevent damage to the product itself, as we want the client to get the most out of the project and not lose it due to a product failure. We must test the durability of our product and ensure it can withstand certain conditions. As we will be mounting the project onto a bar, we have to ensure the mounts are strong enough and find a suitable position for its purpose and easy maintenance, as we do not want injury to occur while servicing the project when it will be necessary.

A safety concern that was not as clear as the rest was a possible fire hazard presented by the Go-Pro Hero 9 camera. After long usage, the camera tends to get really hot. In order to ensure a safe working temperature and keep a safe working environment, we were presented with two options. The implementation of heatsink, or find an alternative method to ensure the device does not reach high temperatures. We ultimately decided that the best approach would be to turn off the system while not in use and only turn it on for the required amount of time to get the task done. Keeping the devices off during transition periods, we not only ensure the temperature does not reach high levels that may overheat the rest of the PhenoCam but can also see benefits in power consumption.

5. Citations

[1] D. Coleman, "GoPro Protune settings explained," *GoPro Tips & Tricks | Have Camera Will Travel*, 04-Jan-2021. [Online]. Available: https://havecamerawilltravel.com/gopro/gopro-protune-settings-explained/. [Accessed: 10-Feb-2022].

[2] "The Essential Guide to Camera Light Meters," *Digital Photography School*, 02-Nov-2021. [Online]. Available: https://digital-photography-school.com/understand-camera-light-meter-desired-exposure/. [Accessed: 10-Feb-2022].

[3] "IEEE Code of Ethics," *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 10-Feb-2022].

[4] KonradIT, "Konradit/goprowifihack: UNOFFICIAL gopro WIFI API documentation - HTTP GET requests for commands, status, livetreaming and media query.," *GitHub*. [Online]. Available: https://github.com/KonradIT/goprowifihack. [Accessed: 10-Feb-2022].

[5] "Rain Gauge Model RG-9," *Rain Sensors*. [Online]. Available: https://rainsensors.com/products/rg-9/. [Accessed: 10-Feb-2022].

[6] "Real Time Clocks (rtcs) in Microcontroller Timers - technical articles," *All About Circuits*. [Online]. Available: https://www.allaboutcircuits.com/technical-articles/introduction-to-microcontroller-timers-real-time-clocks/. [Accessed: 10-Feb-2022].

[7] "What is a light sensor? Types, Uses, Arduino Guide," *Latest Open Tech From Seeed*, 05-Jun-2020. [Online]. Available: https://www.seeedstudio.com/blog/2020/01/08/what-is-a-light-sensor-types-uses-arduino-guide/. [Accessed: 10-Feb-2022].

[8] "Wind Sensor Rev. C," *Modern Device*, 07-Feb-2022. [Online]. Available: https://moderndevice.com/product/wind-sensor/. [Accessed: 10-Feb-2022].

[9] L. Day, "Choosing the right RTC for your project," *Hackaday*, 30-Sep-2020. [Online]. Available: https://hackaday.com/2020/09/30/choosing-the-right-rtc-for-your-project/. [Accessed: 22-Feb-2022].

[10] M. Stone, "How to choose a microcontroller," *Adafruit Learning System*. [Online]. Available: https://learn.adafruit.com/how-to-choose-a-microcontroller/kinds-of-microcontrollers. [Accessed: 22-Feb-2022].

[11] *I2C*. [Online]. Available: https://learn.sparkfun.com/tutorials/i2c/all. [Accessed: 22-Feb-2022].

[12] S. Chandrasekaran, "Interfacing RTC with microcontroller," *Embed Journal*, 14-May-2013. [Online]. Available: https://embedjournal.com/interfacing-rtc-with-microcontroller/. [Accessed: 22-Feb-2022].

[13] "Electrical and electronics engineers : Occupational outlook handbook," *U.S. Bureau of Labor Statistics*, 08-Sep-2021. [Online]. Available: https://www.bls.gov/ooh/architecture-and-engineering/electrical-and-electronics-engineers.htm. [Accessed: 22-Feb-2022].