Aerial Imaging and Lighting

Final Project Plan for EENG383

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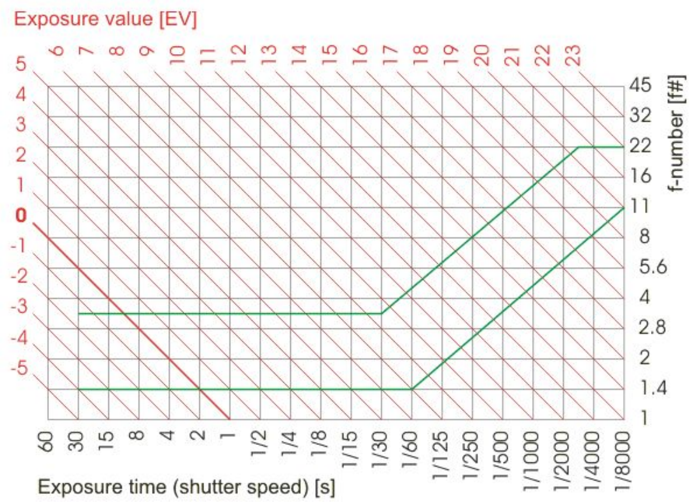
CHAPTER 1: Design Goals

BACKGROUND

Cameras are a revolutionary device that have changed modern society through the hands of photographers. Lighting is one of the most important factors that photographers take into account when composing a shot. Often times professional photo shoots will have lighting equipment on site to help create a beautiful image. These lighting fixtures are essential to the quality of the images a photographer can capture.

In the world of photography creating the perfect image includes balancing several different settings to create stunning photos. The three main elements that are controlled by the photographer on the camera are shutter speed, ISO, and aperture. The shutter speed modifies how long the shutter is open and allows light to hit the image sensor. ISO refers to the image sensor's sensitivity and the aperture (also referred to as the f#) adjusts how much light enters the camera lens. To make the environment accommodate the photographer's preferred settings for shutter speed, ISO, and aperture, they often use lighting equipment. This studio equipment can range from a few hundred to thousands of dollars and is an investment for photographers [1]. Photographers represent the combination of factors (f#, ISO, & shutter speed) as a number that is called exposure value. Identical exposure values can be achieved by varying the different factors in the camera's settings. If the exposure value is too high the image will appear over exposed, whereas if it is too low the image can be underdeveloped and can be fuzzy. This chart shows how cameras with an auto mode will automatically balance shutter speed and the aperture (f#) to create an acceptable Exposure Value [2].

Figure 1: *Chart showing the different values for shutter speed, f#, & ISO and the calculated Exposure Value.*



With advancements in digital technology that allow cameras to make estimates on these three aspects (f#, ISO, & shutter speed) to compose perfect photos the camera is finding its way into all kinds of technology. A new and popular application is on camera drones and the FAA states, the number of hobby drones is expected to reach from 1.9 million in 2016 to 4.3 million by 2020 [3].

These onboard cameras have many technical features like shutter speed adjustment but lack the ability to shoot in low light settings and balance lighting. Top end camera drones give the user the ability to adjust shutter speed or ISO but not aperture which can affect the exposure of an image. In order to balance the lighting for pilots who want a higher ISO or slower shutter speed there are filters designed to balance the lighting. The disadvantage of using filters is that only one can be used at a time and changing the filters can take a significant amount of time and if the drone is on can drain the battery so there will be less time to actually be flying. Also it is difficult to determine the appropriate filter from a ground vantage point as the lighting can change once the camera drone is above obstructions like trees and buildings.

There is a need for a constant lighting source that balances the light of a setting to help camera drone pilots compose high quality images with ease.

MARKETING

- The aerial photography field is rapidly growing, and equipment to match the current capabilities of handheld cameras will be in high demand.
- Achieving an optimal level of lighting is one of the main requirements for capturing high quality images.
- The solution is an onboard lighting fixture that can be adjusted in flight.
- Wireless control of the lighting fixture will allow the photographer to create optimal lighting for a shot, without changing the position of the drone.
- Automated adjustment by the device will allow easy and seamless use of the fixture.
- Drone battery life is very limited and only a few shots can be set up before the drone must be recharged.
- An onboard lighting fixture will decrease the time between shots and allow more images to be taken on a single battery charge.
- The fixture will allow the drone to be safely flown in low light conditions.

LEVEL 0

To achieve a portable lighting module that can be used for camera drones, the team will implement the use of 2 HCS12 microcontroller units that will communicate with each other using radio communication. One of the microcontroller units will serve as a remote that will display data collected by the second unit. It will also have a dial for users to manually adjust the lighting settings. The second unit will be connected to the LED array. It will transmit the data from the onboard light sensor to the display and control the LED brightness level from the user's preferences. Since the system will be in continuous radio communication, the lighting unit can also automatically adjust the LED brightness when the ambient light changes. Below is a block diagram which shows how the system will achieve the intended goals.

Figure 2: *Level 0 diagram to represent the necessary components.*

Block Diagram:

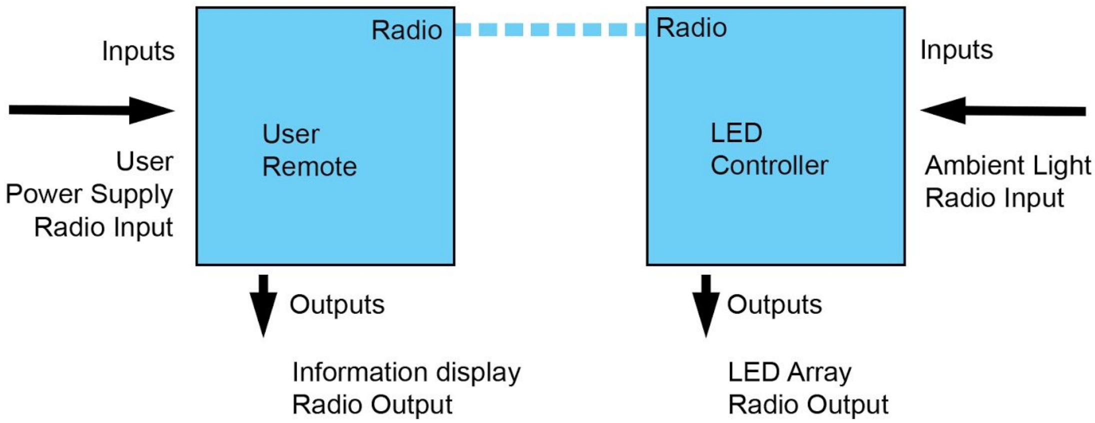


Table 1: *Describes the inputs for the remote unit.*

User Remote Inputs	Decription
Power	The remote will be powered by a battery.
Lighting adjustment control	The user can manually adjust the brightness of the LEDs using a knob on the receiver device.
Radio input	The remote device will get information from the controller about its parameters such as LED brightness.

Table 2: *Describes the outputs for the remote unit.*

User Remote Outputs	Decription
Information display	An LCD screen will be used to display information about the system to the user.
Radio output	The manual lighting control settings will be sent to the LED controller.

Table 3: *Describes the inputs for the LED unit.*

LED Controller Inputs	Decription
Power	The LED controller will also be powered by a battery mounted on the drone with the LED array and board.
Ambient light sensor	A photoresistor will be used to gather information about the current level of ambient light.
Radio input	Lighting control settings will be received from the remote unit.

Table 4: *Describes the inputs for the LED unit.*

LED Controller Outputs	Decription
LED array control	The controller unit will adjust the brightness of LED array using an amplifier or something similar.
Radio output	Information about the controller unit will be sent back to the remote unit.

CHAPTER 2: Detailed Design

Detailed Architecture

The Level 1 diagram serves to represent a more detailed configuration to the planned project setup.

Figure 3. *Representation of the modules used and the connections between the components.*

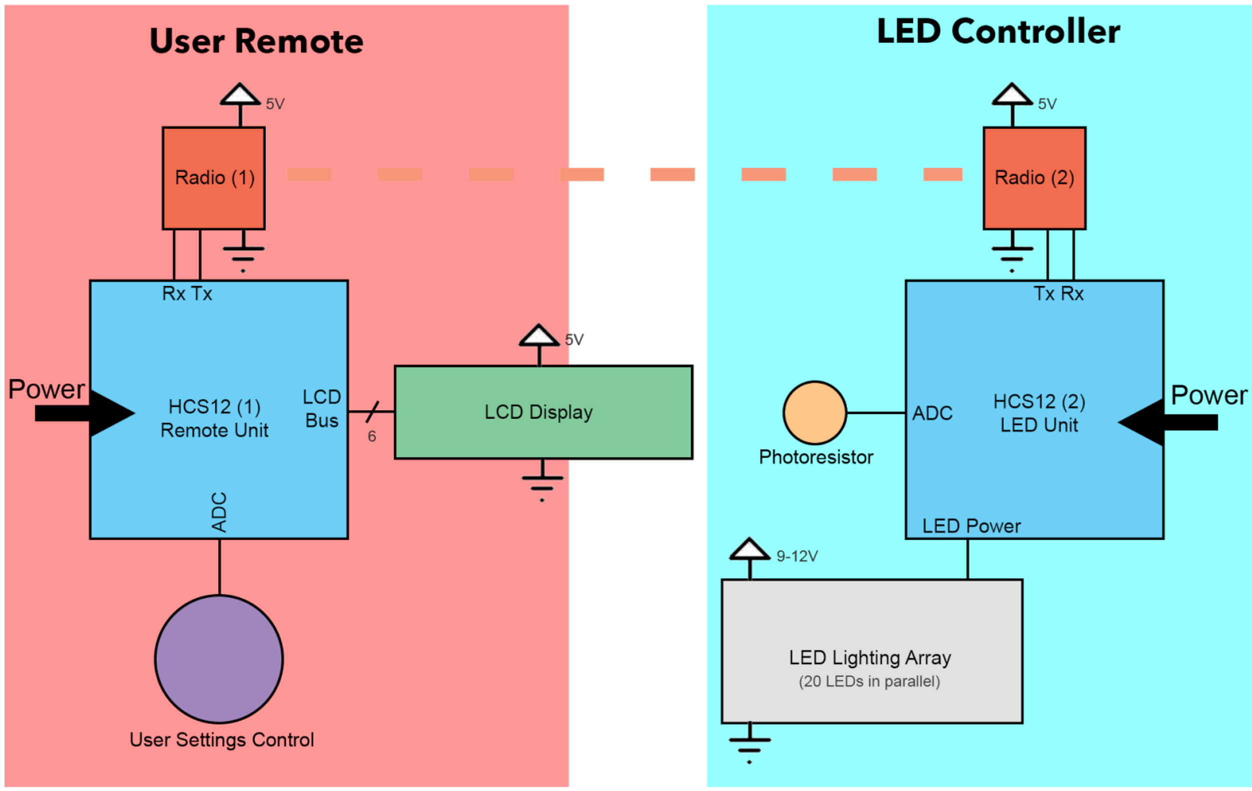


Table 1: *Describes the inputs, outputs, and behavior of the remote unit HCS12 module.*

Module	HCS12 Remote Unit
Inputs	Power - the HCS12 is powered by 5V DC, which will come from a power regulator attached to a battery. Radio - operates on Rx channel at slave bit rate of up to 300 bit/s (set by HCS12) User settings - rotary switch will operate in digital 5V
Outputs	LCD - 4 bit port will be used to output to LCD Radio - operates on Tx channel at slave bit rate of up to 300 bit/s, 100mW max
Behavior	The remote unit will get user input from rotary switches. This input will be transmitted over the radio and also displayed on the LCD screen. It will also get information from the radio which will be displayed on the LCD.

Table 2: *Describes the inputs, outputs, and behavior of the LCD on the remote unit.*

Module	LCD
Inputs	Power - the LCD screen will likely operate at 5V Ground - connected to Vss on HCS12 Data - 4 bit bus which transmits data or instructions from HCS12, 0.1 second refresh rate RS - 1 bit wire connected to HCS12, 0 for instruction, 1 for data R/W - 1 bit wire to specify read (1) or write (0), tied to ground CS - sets LCD clock, connected to PWM output on HCS12
Outputs	Screen - user output which will display information about the system
Behavior	The LCD will continuously receive formatted data from the HCS12, 4 bits at a time over the data bus, and display this information on the screen.

Table 3: *Describes the inputs, outputs and behavior of the radio module on the remote unit.*

Module	Radio
Inputs	Power - connected to Vcc on the HCS12 Ground - connected to Vss on the HCS12 Tx - sets frequency to HCS12 frequency, up to 300 kHz
Outputs	Rx - sets frequency to HCS12 frequency, up to 300 kHz Antenna - transmits Tx data with up to 100mW signal power
Behavior	The radio transmits data from the Tx line connected to the HCS12 and receives data which is sent over the Rx line.

Table 4: *Describes the inputs, outputs and behavior of the HCS12 module on the LED unit.*

Module	HCS12 LED Unit
Inputs	Power - the HCS12 is powered by 5V DC, which will come from a power regulator attached to a battery. Master switch in series with LEDs and power regulator. Radio - operates on Rx channel at slave frequency up to 300 kHz ADC - HCS12 will poll the ADC 10 times per second for lighting information from the photoresistor
Outputs	Radio - operates on Tx channel at slave frequency up to 300 kHz, 100mW max LED array - LED array will be connected to Op-Amp which will be connected to PWM channel of HCS12, varying duty cycle will adjust brightness
Behavior	The LED unit will get information from the remote unit about how bright to make the LED array. When the remote unit is set to AUTO mode, the LED unit will automatically adjust the brightness based on the photoresistor data. It will also

	transmit photoresistor, brightness, and battery information back over radio.

Table 5: *Describes the inputs, outputs and behavior of the photoresistor on the LED unit.*

Module	Photoresistor
Inputs	Power - connected to Vcc on the HCS12 Light - the photoresistor will change its resistance based on how much light it is exposed to
Outputs	Signal - connected to AN02 on the HCS12
Behavior	The photoresistor will change its resistance based on the amount of ambient light. The changing voltage drop across the photoresistor will cause the voltage sunk by the HCS12 to change, which will be measured by the ADC.

Table 6: *Describes the inputs, outputs and behavior of the LED Array.*

Module	LED Array
Inputs	Power - connected to a Mosfet which is connected to HCS12 and battery positive Ground - connected to battery negative
Outputs	Lighting - 100W LED array outputs light from the drone
Behavior	The LED array brightness is controlled by the HCS12.

Calculations

The following calculations serve as guidelines to base our modeling and prototype construction off of. The calculations are based on the information that was collected about the hardware we intend to use.

Timer interrupt to poll the photoresistor 60 times a second (see *Parameters #5*).

$$\frac{24{,}000{,}000\ clocks}{1\ sec} \bullet \frac{1\ conut}{8\ clocks} \bullet \frac{1\ trigger}{X\ counts} = \frac{60\ triggers}{1\ sec} \quad X = 50000\ counts$$

Battery and LED calculation for battery specs and LED consumption.

$$\frac{720\ mAh \bullet 3\ batteries}{900\ mA \bullet 20\ LEDs} \bullet \frac{60\ minutes}{1\ hour} = X\ minutes \quad X = 7.2\ minutes$$

---Operating voltage of 11.1 volts.---

Technical Requirements

This project's technical requirements are based off of characteristics to maximize usability and performance for photographers and videographers using Phantom 4 drones. This drone is being selected as a benchmark because it is the most common industry leading consumer cinematic drone.

Parameters:

1. LED unit must weigh less than 2lbs. Dependent on maximum load capacity of the Phantom 4 quadcopter [4].(This includes: LED Array, Photoresistor, HCS12 microcontroller, On-board Radio, Power Supply, & Structural Harness)
2. 1500-1000 lumens produced - The LED array needs to provide the average lighting requirements for studio lighting.
3. Strong radio connectivity for up to 250 ft. - The remote and LED unit must be able to have a strong connection for effective flight distances. (Based off of the output of studio lighting.)
4. About 7 minutes of full power lighting - The average flight time of the Phantom 4 drone is 15 minutes so for about 50% of the flight the light can be at full power.
5. Frequent adjustment checking at least 60 times a second - The modules must read values often to have an accurate lighting when in auto mode. It should be at 60 times a second because that is twice as fast as a cinematic frame rate so the camera will not be able to pick up 'flickering'.

Bill of Materials

Cost Breakdown:

Estimated Total Project Cost:	**$51.83**
Cost to University:	$14.25
Personal Cost:	$37.94
Cost uncertainty*:	$15.00

**The uncertainty cost is the sum of potential costs from materials that we are uncertain whether the university has available for academic use.*

The materials needed to produce the project include:

Table 7. *Components that are expected to be utilized in the aerial lighting project.*

Product	Cost	Purchase	Source
HSC12 (2)	-	Mines	-
Photoresistor	-	MInes	-
Op Amp	$0.95	Sparkfun	COM-09456
Battery - LED	$21.59	Personal	PS [2]
9V Battery -Remote	$1.00	Personal	-
LED Array	$15.99	Personal	PS [1]
Radio (2)	$4.95	Sparkfun	COM-13909
LCD display	-	Mines	-
Rotary Switch (2)	$0.95	Sparkfun	COM-09939
2 state switch (2)	$0.75	Sparkfun	COM-09609
5V Power Regulator	-	-	-
Resistors	-	Mines	-
Mounting hardware	-	-	-

Chapter 3: Implementation

Milestone I

1. Display text on the LCD and correctly format the display to show all parameters of the system.

2. Use the HCS12 to vary brightness of the LED array.

3. Read information from the user control input on the remote unit and the photoresistor input on the LED unit.

Milestone II

1. Successfully communicate between the two HCS12 radio modules. Show that information can be received and transmitted by each.

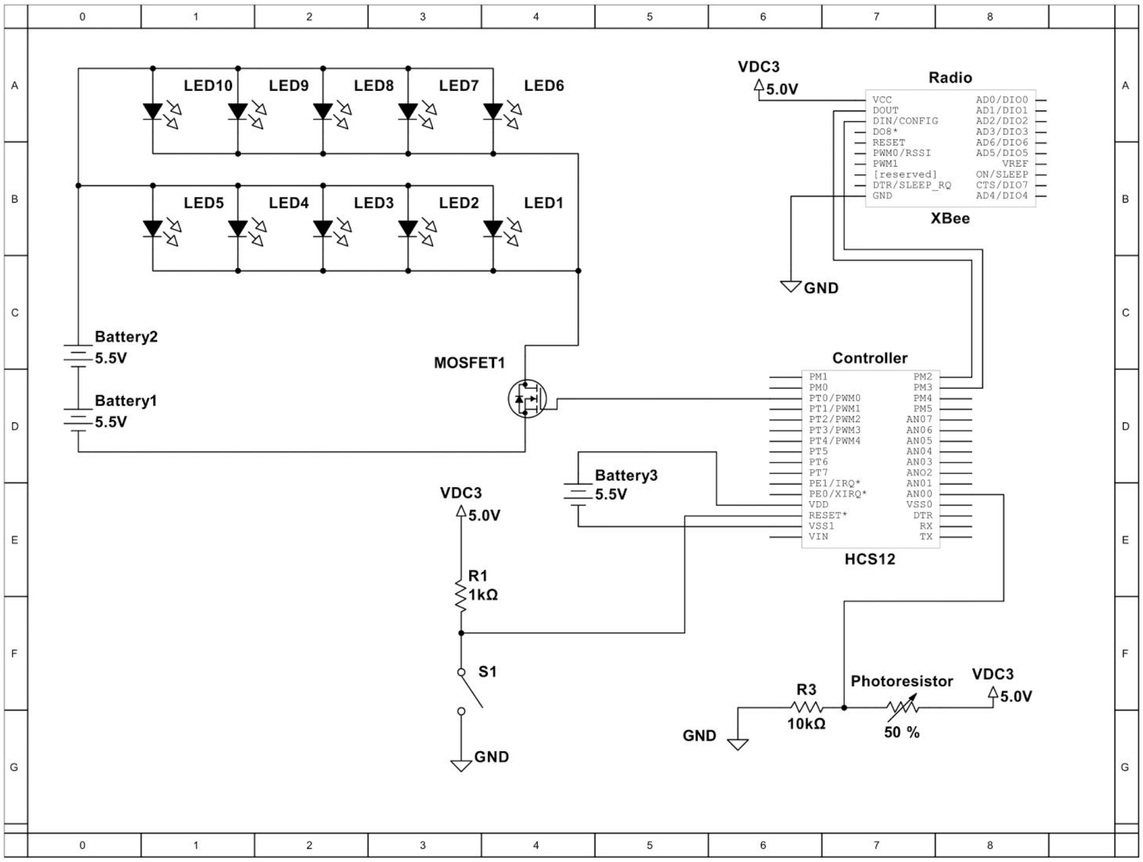
2. Demonstrate that the brightness of the LED array is adjusted automatically after the photoresistor senses a change in the ambient lighting.

3. Display information from the user settings control on the LCD screen.

Final Implementation

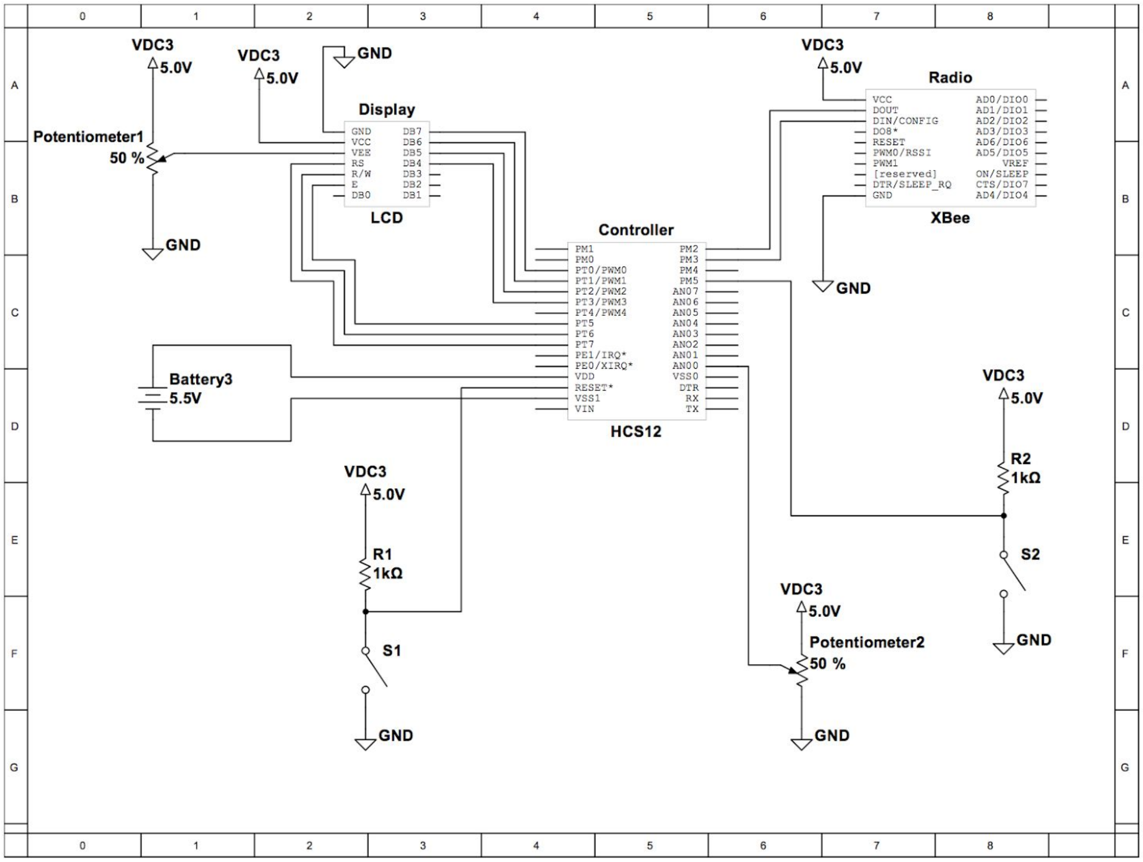
It was necessary to change several aspects of the project design during its final implementation. The system hardware and software will be described as follows.

Figure 4: *Schematic of the LED unit.*



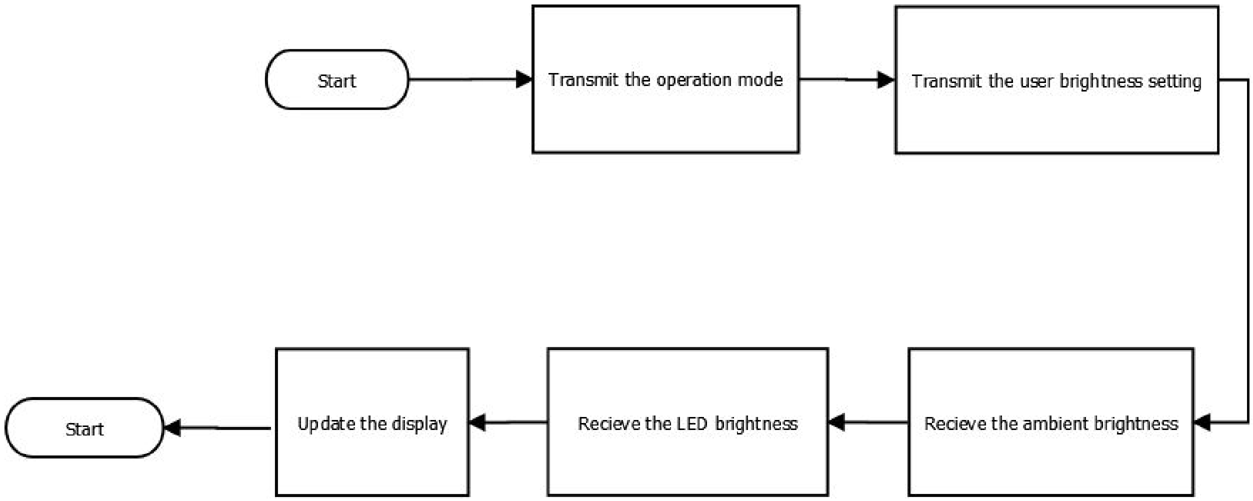
The final implementation of the LED unit can be seen in Figure 4, above. An XBee radio is wired into power and ground as well as ports PM2 and PM3 on the HCS12 for data transfer. The photoresistor is put into a “pull-up” configuration and the output voltage was wired into analog channel 0. The HCS12 is powered by a 5.5V battery connected on its VDD and VSS pins. A push button is connected in “pull-up” configuration on the reset pin of HCS12. Finally, the gate of a MOSFET is wired into the PWM0 channel of the HCS12. The source and drain of the MOSFET are connected to the battery ground and LED array ground accordingly. Two more 5.5V batteries power the LED array.

Figure 5: *Schematic of the Remote unit.*



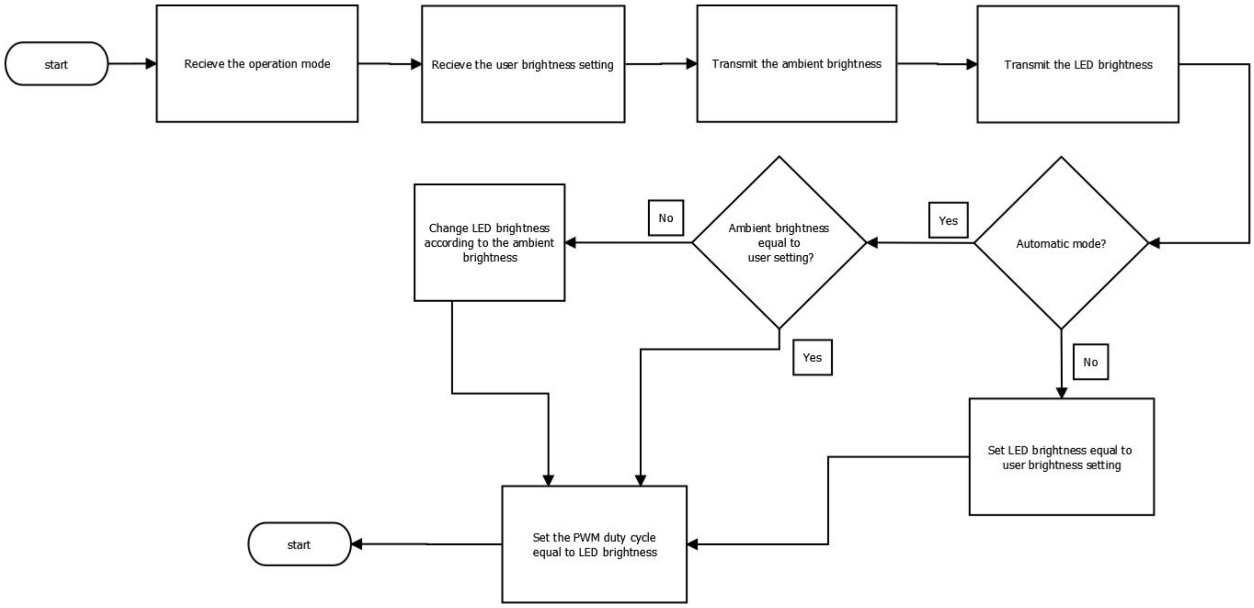
The final implementation of the remote unit is similar to the LED unit and can be seen in Figure 4, above. The power, reset, and radio configurations are identical to the LED unit. The remote unit uses all Port T pins aside from PTT4 to drive the LCD. The LCD is also connected to power, ground, and a potentiometer for contrast adjustment. The remote unit also includes a pushbutton in “pull-up” configuration on PM5 for changing between manual and auto mode. Finally, a second potentiometer is connected to analog channel 0 for brightness setting adjustment.

Figure 6: *Flowchart for remote unit main routine.*



We designed our software to be as simple and reliable as possible while maintaining maximum functionality. The remote unit operation follows a very simple routine. First, it transmits the operation mode and user setting to the LED unit. Next, it receives the current ambient brightness and LED power setting from the LED unit. Finally, it updates the display. This routine will loop as long as the remote unit is turned on and is receiving input from the LED unit over radio. The user setting and operation modes are set in a timer interrupt which is executed every 100 milliseconds

Figure 7: *Flowchart for LED unit main routine.*



The LED unit also starts by receiving and transmitting data between it and the remote unit. Next, it checks whether it is in automatic or manual mode. In manual mode, the LED power is set to be exactly the user setting. In automatic mode, the LED power setting is adjusted based on the input from the photoresistor in addition to the user setting. Finally, the duty cycle of the PWM channel which drives the LEDs is set to the LED brightness setting. This routine will also continue as long as it is on and is receiving radio contact from the remote unit. A timer interrupt is used to poll the value stored in the analog to digital converter and set the ambient brightness variable.

Appendix A:

In order to properly use the Aerial Lighting project, first ensure all wires, connections, and leads are connected according to the schematics for the respective units. The schematics are as follows:

Schematic for the Remote Unit: See Final Implementation (Fig 5).
Schematic for the LED Control Unit: See Final Implementation (Fig 4).

Once the previous instructions are confirmed, proceed to the following steps.

1. Initiate the Remote Unit, connect the SSMI board to a power supply.
2. If the HCS12 is in RUN mode press the RESET button to start the software.
    a. If the HCS12 is in LOAD mode, ensure the appropriate software has been loaded. Then continue to step 3.
3. Initiate the LED Control Unit, press the battery on button to power up the HCS12. Immediately following power on the 2 LED battery sources.
4. Check for a stable radio connection. Try adjusting the potentiometer on the Remote Unit. If the value ‘SET’ does not change, you will need to reconnect the radios.
    a. To reconnect the radios: Ensure close proximity or line of sight for both units. Press the RESET button on the SSMI board of the Remote Unit while the HCS12 is in RUN mode. Retry step 4.
    b. If problems continue, press RESET on the LED unit followed by pressing RESET on the Remote Unit.
5. The radios and HCS12 modules should now be working appropriately. Refer to the operation instructions.

Operation Instructions:

Part	Function	Location
LCD	Display current info.	Remote Unit
Potentiometer	Adjust the User set value	Remote Unit
Button	Toggle AUTO and manual mode	Remote Unit
Photoresistor	Gather ambient light info.	LED Unit
LED Array	Provide light	LED Unit

Change Modes:

- Users can switch between AUTO and Manual modes by pressing the button on the Remote unit to toggle.

Change LED Brightness:

- AUTO mode: In auto mode the brightness is controlled by a combination of the photoresistor and the user setting.
    - If the User setting is above the ambient threshold the brightness will decrease.
    - If the User setting is below the ambient threshold the brightness will increase.
- Manual mode: In manual mode the brightness is determined by the value of the potentiometer. Twisting the potentiometer will either increase or decrease the brightness.

Power Down Instructions:

1. Unplug the SSMI board to turn off the Remote Unit.
2. Remove the connection for the +5V on the breadboard of the HCS12 on the LED Unit. Be sure to reconnect this wire for future use.

References

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[3] V. Sonawane, "Drones in America," *International Business Times*, Mar. 2016.
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[4] https://www.youtube.com/watch?v=E6zZWsWhC8s

PRODUCT SOURCES:

[1] https://www.amazon.com/dp/B019DZ20ZK?psc=1

[2]https://www.amazon.com/gp/product/B01736NLB8/ref=pd_sbs_21_6?ie=UTF8&pd_rd_i=B01736NLB8&pd_rd_r=GE8F4SN1CXNWWXXT8NXE&pd_rd_w=hr5UF&pd_rd_wg=0dVqB&psc=1&refRID=GE8F4SN1CXNWWXXT8NXE

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