Smart Lights

Senior Design One Documentation

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Group 2

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1.0 Executive Summary

Ever since the invention of the light bulb it has become a prevalent aspect on everyday life. The light bulb has become more advanced since the first concept. With the recent innovations in technology it has allowed for light bulbs to be used for more than just lighting a room, it has been changed to be used for car lights, computer screens, TV's, cell-phones, projectors and even led light strips for decorations. The size and amount of energy needed to operate a microcontroller has dramatically reduced in the last few years. With this advancement it has allowed for the light bulbs such as Philips Hue to be controlled by a hub which intern is controlled by a smartphone. With a light bulb being able to be controlled by a smartphone it opens up the door to so many possibilities. For one it allows for the user to turn on or off the light from their smartphone. Also, it means that the user could pick any color they want to set the mood for any event. The user could also use the lightbulbs as a way to set reminders. For example, if the user has a problem waking up in the morning, the user could set a time for the lights to turn on or flicker.

The Smart Light Hub has been made with the consumer in mind. This means that the product will be easy to use while also being reasonably cost. The Smart Light Hub will consist of 3 different components, LED light strips, a smart hub, and smart phone. The Smart Light Hub will consist of multiple LED lights which will be able to change into any color which the user desires. The next part of the Smart Light Hub is the hub. The hub will be the brains behind the entire system. It will contain a microcontroller which will have different components such as the wireless communication chip. This chip will allow the user to change the color of the light from the smartphone and send that data to the hub which will then decode it so that the LEDs can change colors. The final part to the Smart Light Hub is the smartphone. The two computer engineers will create an app which will have a clean user interface so that any person could easily operate the system. The smartphone will use either Bluetooth or Wi-Fi to communicate the information to the hub. In the app the user will be able to change the color of the light while also being able to have set preprogrammed light configurations. The user will also be able to have a mode in which the lights change color to the beat of the music depending on the frequency of the sound. The reason why everything is connected wirelessly is first, it makes it more convenient to transfer from one place to another. It also makes the system light weight. Furthermore, it eliminates the hassle of cable management.

The reason for this document is to record the Smart Light Hub design process. This document will first discuss about the motivation and the goals for this project. Next the document will discuss about the specifications and requirements such as the dimensions and different led lights. Next the document will go on to talk about the research which will include why each component of the Smart Light Hub was chosen.

2.0 Project Description

The Smart Light Hub can be a new way for people to interact with their lights and change the way people think about lighting an area. Say of example an individual wants to have an efficient light source, lights which can change color for events such as birthday parties, Halloween and Christmas or just something to help wake them up in the morning. The Smart Light Hub could fix all of these problems and more.
This Sections contains:

- The motivations and influences of each members responsible for the project.
- The goals and objectives which are expected from the members during the beginning design process of the Smart Light Hub system.
- A in dept. list and description of the requirements and specifications of the Smart Light Hub system.

2.1 Project Motivation

The common person usually spends most their time in one place, their home. When at home there are many mundane tasks which take up a minute amount of time and effort, but this adds up. These tasks include turning on lights and fans, playing music, controlling air conditioning and many more. As technology progresses so does the way we interact with the things around us, thus changing the way we interact with our home. We can now use technology to eliminate or simplify some of these mundane tasks. Home automation, is a growing field which allows users to have control of some household features and appliances. The Internet of Things is what makes home automation possible.

Internet of Things (IoT) is a term which refers to a basic concept in which devices can connect to wireless technology. This includes devices ranging from mobile phones, coffee makers, lights, washing machines and many more. The Internet of things has many uses, such as setting the lights in a user's home to turn on or off at a certain time, allowing the user to change the state of the lights from an application. Many times, the user can also change the color of the lights based if they have the necessary bulb. The Internet of things is very useful, not only for users trying to save time and effort but also for people with disabilities. A user who normally cannot walk to turn on the lights in their home can now use a mobile device to control their lighting.

The motivation behind this project is directly tied to this groups passion for technology and developing products that eliminate mundane task to create simpler lives for people. With current technology, there are endless possibilities for appliances and items to have more advanced capabilities. Currently there are still limited sources for smart home lighting and these sources have a high cost associated. Our proposed project would be a small, low cost and energy smart light hub with a free mobile application associated.

Our group would like to create a product which would simplify a user's life, while learning more about what goes into home automation development.

2.2 Objectives and Goals

The main objective of the Senior Design project is to showcase that the University of Central Florida has provide the necessary education needed to become a competent engineer through their rigorous four-year degree program. The Smart Light Hub system implements technology that is starting to enter the homes of many individuals as the market of IoT (internet of things) continues to grow it is essential to gain the skills to compete in this emerging market. Two member of the group are aspiring to become computer engineers and securing jobs as software engineers. While the other two members are aspiring to become electrical engineers. Both electrical engineers are interested in working on different signal and circuit analyses. This project will test the group's ability to effectively work with different engineering disciplines and ability to conduct research and development to engineer a system that work based on the requirements agreed on. Also, pushing the group to use technology they are unfamiliar with to achieve the goals of the specifications.

Another objective of the project is to make this product simple to use because its indented users may not have an engineering or technology related background. The computer engineers will accomplish this goal by implementing an application for android mobile devices. Giving the users of this product an application with a GUI (Graphical User Interface) will limit the amount of technical knowledge these users will need to have. The time needed to learn to use the system and setup the system will be cut down. To make the application user friendly they will design the application using the best practice of HTI (Human Technology Interaction). The electrical engineers will make the system easy to use by making the Smart Light Hub portable and little. They are going to accomplish this with using various compact wireless and LED technologies.

An additional objective of the project the electrical engineers will achieve through the design process. Is designing compact small PCB using eagle CAD. Both electrical engineering student do not have any experience using the eagle CAD software before. It's going to be a large learning curve for them, but it will give them the opportunity to gain new experiences with designing PCB circuits.

A goal the computer engineers will accomplish with this design project is that the fact. That they get to program a system that has multiple wireless circuits that need to communicate with each other. Giving them the chance to gain additional experience with different wireless standards and protocol.

2.3 Smart Hub Light System Block Diagram

The block diagram in Figure 1 is a depiction of how devices within the smart light hub will interact with one another. Looking at the actual overview of the block diagram, it can be seen that the communication will start from the microcontroller. The microcontroller is basically the central processing unit for the Smart Hub Light System. From the microcontroller, the smart light hub will be powered by an outlet which will be the power supply for the project. The power supply is the main source of power for all of the components of the Smart Hub Light System. The power supply will power the RGB LED lights, the microcontroller and the wireless card. From there the microcontroller will be connected to the Printed Circuit Board (PCB). The purpose for this is because the team feels that the utilization of the PCB will allow the team to implement more components easily rather than having a bunch of wires that are just connected to the microcontroller. On the PCB, the Wi-Fi card will be connected on there and the power supply will supply the voltage onto the PCB. One thing that the team will need for this is a voltage regulator because the Wi-Fi card can only handle a voltage of 3.3 Volts. The overall voltage that the RGB LEDs needs to be powered fully is 5 Volts with an overall current of 2.0 Amps. So overall, the team knows that the PCB will serve as the Hub base for the Smart Hub Light System and the cellular device will be connected through the software application that will be developed using a code that is similar to the Amazon Echo. That does not mean that the team will copy the code, but it means the team will utilize the code as an example of developing the overall functionality of the hardware components.

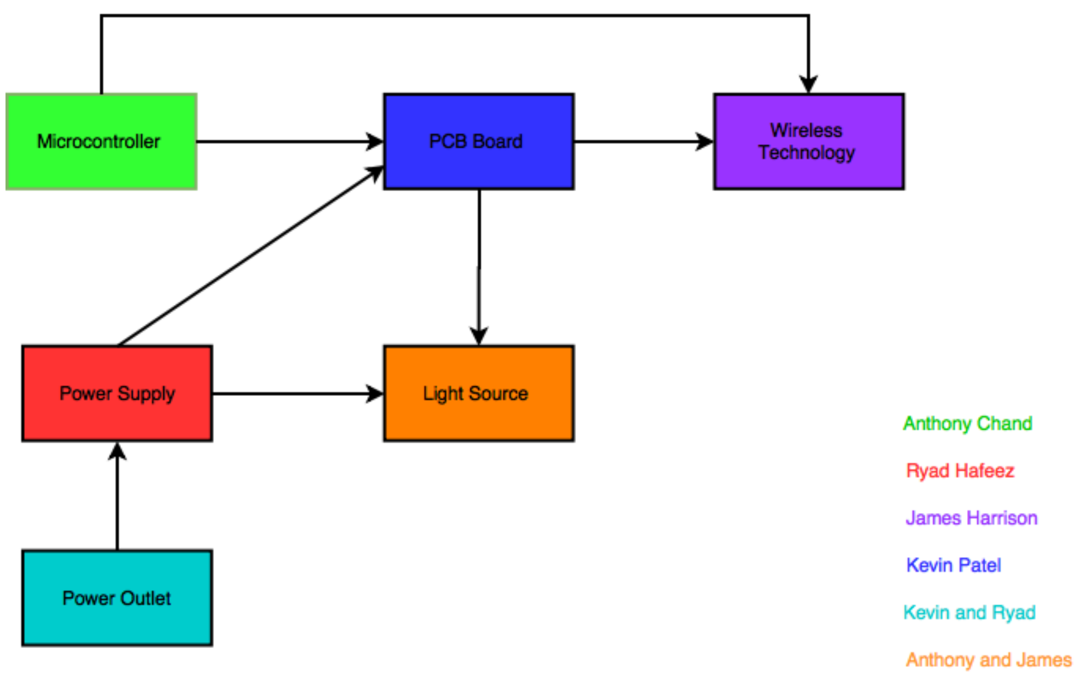


Figure 1- Block Diagram Overview of Smart Hub Light System

2.4 Users

The Smart Light Hub System will target three different type of users. The system is designed to have three different modes of operation. The two groups of individuals that will be using the system, are those who would like to control the mood and general lighting of the room. While the other group will install the product with the intent of using it for party's by lighting the room based on the current music that is being played. The final group of people will use the product with the intention of using all the available modes of operation. The Smart Light Hub is well round system designed with the objective of being marketable to all types of people who are looking for a new lighting system.

2.5 Requirements Specifications

The Smart Light Hub system will have numerous Requirements to warrant its success among other products that offer similar features. To ensure this system stand out from the others product that competitors are making we will target the following requirements, it will have to be able to provide portability, efficiency, user-friendliness, and low cost. The group will put a great deal of effort and time into research and development to accomplish these requirements. We will also try are best to achieve the goals of the requirement with a budget of $250. If needed the group will be able to spend money. Suppose that it is not in the price range due to components being destroyed or using a module or component that does not fit are project anymore because we have found a component that works better. Since we will be self-founding the project it will easy for us to make the theses changes to the budget without having to go through the trouble of working with a sponsor to get additional funding. As a cap on the budget to prevent over spending the group has decided to keep the cost of the entire project under $750.

To guarantee that the Smart Light Hub system is portable the group will be designing a central hub. The hub can be placed in a user's home in any location they find best choose to be best fit. As the system will be connected to the home network. With the system allowed to be palace into any room of the user choose. There needs to be a way to connect to the hub. The group with accomplish this hurdle by developing a mobile application that will connect to the user wireless home network. Once the application is connected to the home network the user can now access the hub system. After the user is connect to the hub system he or she will be given the ability to control the hub, which has permission to issue commands to the light system that it will be connect to. Developing this module system will be difficult but giving the user the opportunity to connect from any location in their home will make it easy to use without having to be within a certain range of the system. Having this convenience allowing the user to connect to the system from any location in their network will have a direct impact on the efficiency of using the system.

To provide efficiency the team will be implementing the proposed system using technology that will interact with each other well. By doing so the group will be able to mitigate the possibility of errors happening. Even though this will have a direct impact on reducing error there will always be a margin of error in the system, it's something that cannot be avoided. Some key items that can have an influence on efficiency is the design of the PCB. It known that not placing components on a PCB can cause interference which results in errors that sometimes can be mind boggling to solve. The electrical engineers will spend a great deal of time working hard to limit the possibility of this happing. Another way that the efficiency of the system can be increase is by using a wireless standard that has a many ways of recovering from error do to congestion of that network or by wireless interference.

The computer engineers in the group will provide consumers with a user-friendly application to interface with the Smart Light Hub system. They will meet this requirement by following some best practices when designing the GUI of the device. They will also work with the electrical engineers to get feedback on how the application is being to design. Some key characteristics that they will like the capture with the application are the following. They will implement these principle in the design of the UI, easy to remember, provide continuous feedback to the user when needed. Also, prevent errors by providing the error handling to the best of their ability so the system does not randomly crash. Another key item they would like to implement is the ability to have the setup of the system to be plug and play with having load and run code the on the individual components of the system so that users do not have to interact with source code which is very user error prone. The electrical engineers will provide user friendly-ness by designing the system so you can use a standard outlet your home.

2.6 House of Quality

The House of Quality is one of the more commonly used Quality Function Deployment matrix methods, primarily used to denote issues and requirements which are important to the planning process. Requirements based off benchmarking data, and market research, into goals to be met by the proposed system. [1]

Table 1 - House of Quality

Positive Correlation	↑
Strong Positive Correlation	↑↑
Negative Correlation	↓
Strong Negative Correlation	↓↓

		Power Source	Dimensions	Weight	Cost
		+	+	-	-
Accuracy	+	↑↑	↓	↓	↓↓
Durability	+	↓	↓	↓↓	↓
Usability	+	↑	↑↑	↑	↓↓
Cost	-	↓	↓	↓↓	↓
Targets for Engineering Requirements		<30 watts	< 12in x 12in x 6 in	< 15 lbs	< $250

The House of Quality shows the correlation between the requirements of the proposed system. The top row represents the engineering requirements and the first column represents the market requirements, and the bottom row represent the targets for those engineering requirements for the proposed system. This matrix can show how strongly certain market requirements can affect Engineering requirements. Some of the engineering requirements for the proposed system are keeping the weight and cost low, to stay within the range of the competitors.

The needs of the system from the point of view of the engineer are shown in the engineering requirements. One of these requirements is a power source. Having a power source will ensure that the system always has enough power to function accurately, also making this system more usable since the user can easily plug it in to use it. Keeping the dimensions of the system small will have a positive correlation with usability, it will be easier for users to move it around. Making the system lightweight can have a negative correlation with accuracy, since components which could make the system more accurate might have to be left out. Light weight components also carry a higher cost, and are not as durable, so there will also be negative correlations for these requirements as well, but being light weight will allow the system to be more usable.

The engineering requirements show the needs of the system from the engineers point of view, and conversely the market requirement how the needs of the system from the customers point of view. For our system these consist of accuracy, usability, durability and cost. The accuracy of the system is how often system performs the correct action chosen in the android application by the user. Accuracy is usually measured as a percentage and should be as high as possible. A customer would want a durable product, so the more durable a product is the better. Usability of the product can be interpreted as how easily and well a user can use a product, thus the easier this system is to use, the better. All customers will be more willing to purchase a product if the price is cheaper, so keeping the cost low is very important.

3.0 Research

Research is a vital part for any project. To understand technologies that already exist in the current market is vital for developing a system that can stand out from the competitors. For the Smart Light Hub system, research went into the various hardware components such as the microcontroller, PCB, and smart lights. Research also went into the technologies that will be used for the wireless communication between the smart phone and smart LED lights.

3.1 Related Existing Products

The proposed Smart Light Hub system will not be the first of its kind. The Internet of things is a growing field, and as a result there are companies who have developed similar products. It is important to be aware of existing technology or competitors, to not only learn from them, but to be aware of what features are supported by these competitors. As engineers when developing a product being creative and innovative is important, knowing about competitors gives an idea of what's out there currently, thus more creative ideas can be formed on top of the current technology. Some of the most popular competitor's systems are described below.

3.1.1 Philips Hue

Hue is a personal lighting system developed by Philips, which lets a user wirelessly control lights in their environment of choice with a device, such as a mobile phone. Philips designed Hue to be a 4-component system, these components are the Applications, Bridge, Portal, and Lights.

Philips uses applications to control the lights. These applications are capable of many operations, ranging from merely turning the lights on or off, to changing colors and brightness of the lights. The states of the lights can be controlled by user input, or another form of input such as sensors. Philips allows any form of technology which can implement their hue system API's to control their light. [2]

The Bridge is used to allow the smart bulbs used with the Philips Hue system to communicate among each other, as well as with the portal through the internet. Most Hue system API's are to enable users to control every setting of their lights system. With Philips Hue, the bridge and application must be on the same local network, since direct access to the bridge is required by the API's. [2]

To connect the user's environment of choice to the internet Philips uses a web based control panel called the Portal. This portal doesn't just connect the system to the internet, it updates software on the bridge, and delivers outside control commands. [2]
the lights are the final component of the Philips Hue system. In its simplest form the previous components can be considered input while the lights are the output of the system. The Philips smart bulbs consist of 3 types of LED which are chosen to produce

many different intensities and colors. These lights also extend their range by creating a mesh network with the other lights in the system, this network allows the lights to pass messages to each other. ZigBee Light Link, an open standards protocol is used to connect the lights to the bridge. [2]

Figure 2 - Philips Hue System, Bulbs and Bridge and LIFX LED and Application

3.1.2 LIFX

LIFX is a lighting company which in 2012 created the first Wi Fi enabled, multi colored LED. This LED was designed to be the brightest and most flexible light for users, to last about 22 years and could be controlled from a user's smart device. [3] on a 2.4GHZ spectrum LIFX bulbs use channels 1 through 11 to communicate. [4] With the LIFX app a user can fully control the state of bulbs, by switching them on or off, adjusting brightness and color, as well as setting sleep and wake timers.

Unlike the Philips Hue system LIFX bulbs do not communicate with a bridge, the user can control each individual bulb separately, control specific rooms or the all the bulbs in the home, as well control them with normal light switches. [5]

3.1.3 The Smart Light Hub Proposed System

The proposed smart light hub system is very similar in some ways to the competitor systems described above. All systems have a main objective of providing easy, customizable, smart lighting options for a user. The proposed system has more in common with the Philips Hue system, as the LED's which will be created for this system will not have individual Wi-Fi, such as LIFX LED's. The proposed system will use a mobile application and utilize wireless communication to connect with a hub which will then pass the instructions from the application to the LED's. This implementation is like Philips Hue, since with the Hue system, an application passes instructions to a bridge which uses wireless communication to control the lights.

3.2 Microcontroller

The Smart Light Hub will utilize one microcontroller for the hub which will control the various LED light strips to perform different tasks. The microcontroller is the key component for the system. The reason being that it will transmit data from the user who is controlling the lights from a smart phone. The data will then be transmitted to the smart hub though wireless commination. The data then will be processed in the microcontroller which will send the memory to the ram and then change the different LED lights depending on what the user requested. The microcontroller which is chosen should have all the functionally which we need but also be cost efficient. Not only that but the microcontroller should be low-power to perform simple tasks for example transferring data from the smart phone to the smart hub and processing the information to the LED lights.

3.2.1 Microcontroller Options

There are countless microcontrollers out there in the market today. The Team had a broad range of microcontrollers to choose from rather than it being from Raspberry Pi, Atmel, or Texas Instruments. After countless research between the different brands we focused on the main priorities, the first one was being the price and second being the performance, and last being the efficiency of each microcontroller. We felt that the selection from TI (Texas Instruments) was the best for the project since the team members have had experience in working with TI microcontrollers while also being at a good price point.

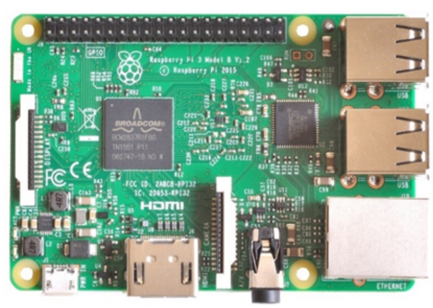
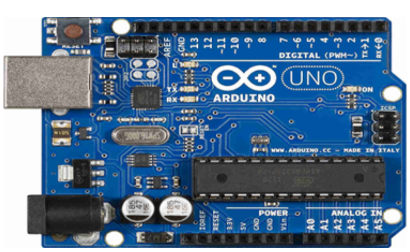



Figure 3A -TI MSP430G2553 *Figure 3B - TI MSP430FG618* *Figure 3C -Raspberry Pi 3*



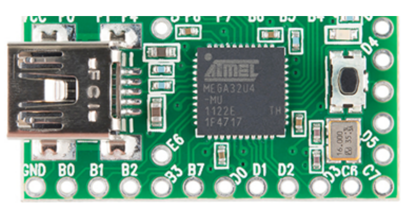



Figure 3D - Arduino Uno *Figure 3E - Teensy 2.0* *Figure 3F - Arduino Uno WI-FI*

3.2.1.1 TI MSP 43x Series

The MSP 43x Series was the first microcontroller series considered by the team. The reason why the team was considering this microcontroller is because of the experience that the team has had in their previous coursework. Given the scope of this project, the team felt that the TI MSP43x Series would be useful in the development of the Smart Hub Light System because the team wants a microcontroller that can perform multiple tasks. One good thing about these types of microcontrollers is that these microcontrollers do not consume a lot of power. Another great feature about using this microcontroller would be that because the University of Central Florida has the TI Lab, the team would be able to gain an overall working knowledge of how the microcontroller works. Since these microcontrollers are heavily marketed by Texas Instruments, there are numerous resources that can assist the team in developing the overall software for their Smart Light Hub.

3.2.1.2 TI MSP430G2 LaunchPad

The MSP430G2 LaunchPad is one of the first microcontrollers that electrical and computer engineering students are exposed to at the University of Central Florida. The MSP430G2 LaunchPad kit comes with two different microcontrollers and a MSP-EXP430G2 breadboard. This kit features an integrated flash emulation tool that allows the team to program and debug any MSP430 Value Line Device. The way that this LaunchPad communicates on the computer is through a USB wire. The main reason why this LaunchPad caught the attention of the team is because of the power consumption for this microcontroller. Not only that, but the team was interested in using this microcontroller because of the amount of resources that are available in the Texas Instruments Lab at the University of Central Florida. One feature that caught the eye of the team was that this LaunchPad contains two microcontrollers. The first microcontroller is the MSP430G2553 and the second microcontroller is the MSP430G2452

3.2.1.3 TI MSP430G2553 Microcontroller

This microcontroller is included in the TI MSP430 LaunchPad Kit. It offers an 8-kB flash memory with a 256 Byte RAM memory. The microcontroller includes 16 GPIO pins. This microcontroller uses 230µA at 1 MHz frequency. This microcontroller is a part of the ultra-low power consumption family. With the TI MSP430G2553, it can supply a voltage range in between 1.8 Volts and 3.6 Volts.

3.2.1.4 TI MSP430G2452 Microcontroller

This microcontroller is also included in the TI MSP430 LaunchPad. This microcontroller offers a 16-kB flash memory with a 512 Byte RAM memory. This microcontroller is also a part of the ultra-low power consumption family. It uses 220 µA at a frequency of 1MHz. Like the MSP430G2553, this microcontroller supplies a voltage range in between 1.8 Volts and 3.6 Volts. The differences between the TI MSP430G2553 and the TI MSP430G2452 as noted by the team is that the TI MSP430G2452 has more flash memory and RAM memory which will be more useful for the team because a higher memory will be able to produce faster results, which is one goal that the team wants for their Smart Hub Light.

3.2.1.5 TI MSP430FG4618 Microcontroller

The next controller that the team decided to research is the MSP430FG4618 microcontroller. This microcontroller offers a 116kB flash memory and an 8kB RAM memory. This microcontroller is also a part of the ultra-low power consumption family. This microcontroller uses 400 μA at a frequency of 1MHz. This microcontroller supplies a voltage in between the range of 1.8 Volts and 3.6 Volts. Another key feature for this microcontroller is that the internal components contains three different operational amplifiers. While this microcontroller offers a higher memory, the cost of this microcontroller is $117.92**.** In terms of the goals of this project, the team feels that to pay that amount of money so that the microcontroller can communicate between a cellular device and a few strips of LEDs is highly unreasonable.

3.2.1.6 Raspberry Pi 3 Model B

This device is neither a microcontroller or microprocessor. It is more of like a mini computer. However, this device can be configured to operate like a microcontroller. Like a microcontroller, the Raspberry Pi contains GPIO header pins. The exact number for this model of the Raspberry Pi is 40 GPIO header pins. This device contains 4 USB ports, 1 HDMI port, 1 Ethernet port, and a 1.2 GHz 64-bit Quad-core ARMv8 CPU. The price for this device is $35.00. While the cost for this device is cheap, the team felt that this would defeat the purpose of the Smart Hub Light because the overall idea of this project was to implement a microcontroller capable of communicating with a cellular device and the LED strips either by WIFI or Bluetooth. Essentially this device would eliminate the purpose of designing and developing a Smart Hub Light System because everything that the team is trying to accomplish has already been developed with this device. A figure displaying the Raspberry Pi 3 Model B can be found below.

3.2.1.7 Arduino Micro

The Arduino Micro is a small microcontroller which can be used for multiple small tasks. The microcontroller board is based on the Atmega32u4 which is developed in conjunction with Adafruit. The microcontroller has 20 digital input/output pints 7 of which can be used for PWM and the other 12 as analog inputs. The Micro has a 16 MHz crystal oscillator, a micro USB connection, ICSP header, and a reset button. The Input voltage is between 7-12V and the power consumption is 29mA. The operating voltage is at 5v and the flash memory is 32 KB of which 4KB is used by the bootloader. The price for an Arduino Micro is around $25. That makes it at the same price point as the Arduino Uno.

3.2.1.8 Arduino Uno

The Arduino Uno is a microcontroller which is used by many electrical engineers. The reason being that the board is based on the ATmega328. The Uno has 14 digital input/output pins, 6 analog inputs, a 16MHz ceramic resonator, a power jack, ISCSP header, reset button and a USB connection. The great thing about the Uno is how easy it is to work. Just connect the USB to a computer and plug the Uno to a power source and its ready to go. The operating voltage for the Uno is 5v and the flash memory is 32 KB of which .5KB is used by the bootloader. The price of the Arduino Uno Rev3 is around $25. This makes the Uno a great value compared to other microcontrollers out there in the market.

3.2.1.9 Arduino Mega

The Arduino Mega is like the Uno but is used for more demanding applications. The Mega is a microcontroller board which is based on the ATmega2560. The Mega has over 3 times the digital input/output pins compared to the Uno. It has 16 analog inputs, a 16 MHz crystal oscillator compared to the ceramic resonator in the Uno. This makes the Mega more reliable since crystals are more stable. A USB connection, power jack, ICSP header, 4 UARTs and a reset button. The Mega is just as simple to operate as the Uno, just plug in the USB to the computer and add a voltage source and it should be operational. The input voltage for the mega is between 5-12V and the power consumption is 38mA. The operating voltage is 5v and the flash memory for the Mega is 256KB of which 8KB is used by the bootloader compared to the Uno’s 32KB. This means the Mega can send and store a lot of information which can be helpful for the project since there will be preprogrammed light configurations which will require more memory. The increase in pins and flash memory come with a price. The Arduino Mega has a price of around $46. This makes it almost twice as much as the Uno.

3.2.1.10 Teensy 2.0

The Teensy 2.0 microcontroller is another microcontroller that is similar to the Arduino microcontroller except that the Teensy 2.0 microcontroller can process more data bits more quickly. The processor that is being utilized for this microcontroller is a 64 Megahertz 8-bit AVR ATMEGA32U4 processor. The flash memory that this microcontroller can hold is 32,256 bits and the RAM memory that this microcontroller can hold is 2,560 bits. The input or output pins for this microcontroller is 25 pins and the voltage rating for this microcontroller is 5 Volts. This microcontroller has 12 analog inputs and 7 PWM pins. The microcontroller is compatible with the Arduino software and libraries and works well with windows, Mac OS X and Linux. The cost for this microcontroller is $16.00.

3.2.1.11 Teensy ++ 2.0

The Teensy ++2.0 microcontroller is similar to the Teensy 2.0 microcontroller except that it uses a different model processor. The processor used for this microcontroller is a 16 Megahertz 8-bit AVR AT90USB1286 processor. The flash memory that comes with this type of microcontroller is 130,048 bits and the RAM memory that comes with this microcontroller is 8,192 bits. The amount of input or output pins that this particular microcontroller is 46 pins and the voltage rating for this particular microcontroller is 5 volts. This microcontroller contains only 8 analog input pins and 9 PWM pins. Comparing this microcontroller with the Teensy 2.0, the Teensy ++2.0 contains more flash and RAM memory and more PWM pins than the Teensy 2.0, however the Teensy ++2.0 contains less analog input pins than the Teensy 2.0. The overall cost for this microcontroller is $24.00. This microcontroller is compatible with the Arduino software and libraries and works well with most computer operating systems.

3.2.1.12 Teensy 3.0

The Teensy 3.0 microcontroller is another microcontroller that utilizes the same Arduino libraries and software and is compatible with almost any computer operating system. The processor that is being utilized is a 48 Megahertz 32-bit ARM Cortex-M4 MK20Dx128 processor. The flash memory that comes with this microcontroller is 131,072 bits and the RAM memory that comes with this microcontroller is 16,384 bits. The amount of input or output pins that comes with this microcontroller is 34 pins and the voltage that this microcontroller is rated at is 3.3 volts. The amount of analog input pins that are present for this microcontroller is 14 and the amount of PWM pins on this microcontroller is 10 pins. The cost for this microcontroller is $19.00. Comparing this microcontroller with the other two Teensy microcontrollers, it can be seen that this is cheaper than the Teensy +2.0 but more expensive than the Teensy 2.0. This particular Teensy model can only operate at 3.3 volts while the other two models can operate at 5 volts.

3.2.1.13 Teensy 3.1

The next Teensy microcontroller is the Teensy 3.1 microcontroller. This microcontroller can still utilize the Arduino libraries and software and is compatible with most of the computer operating systems that are available today. The processor being utilized for this microcontroller is a 72 Megahertz 32-bit ARM Cortex-M4 MK20DX256 processor. The amount of flash memory that comes with this microcontroller is 262,144 bits and the amount of RAM memory that comes with this microcontroller is 65,536 bits. The amount of input or output pins that are present on this microcontroller is 34 pins. This microcontroller can handle both 3.3 volts and 5 Volts input and output voltages. The amount of analog input pins that are present on this microcontroller is 21 pins and the amount of PWM pins that are present on this microcontroller is 12 pins. The cost for this microcontroller is $19.80. Comparing this microcontroller with the other Teensy microcontrollers, one thing that can be noted is that this microcontroller can handle both 3.3 volts and 5 volts input or output. Another feature about this microcontroller is that for $19.80, you can get one of the fastest microcontrollers. This price is still cheaper than the

Teensy ++2.0 microcontroller, but still more expensive than the Teensy 3.0 and Teensy 2.0.

3.2.1.14 Arduino YUN

One microcontroller that the team was looking into was the Arduino YUN. The reason why the team was looking into this microcontroller is because Arduino YUN is the perfect board to use when designing connected devices and, more in general, Internet of Things projects. It combines the power of Linux with the ease of use of Arduino. The Arduino Yun is a microcontroller board based on the ATmega32u4 and the Atheros AR9331. The Atheros processor supports a Linux distribution based on OpenWrt named Linino OS. The board has built-in Ethernet and Wi-Fi support, a USB-A port, micro-SD card slot, 20 digital input/output pins (7 of them can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and 3 reset buttons. The overall cost for the Arduino Yun is around $60. In terms of the cost, this microcontroller costs way too much and is not as beneficial to the Smart Hub Light System as the other cheaper Microcontrollers, like the Arduino Micro or the Arduino Uno. In some countries, it is prohibited to sell Wi-Fi enabled devices without government approval. While waiting for proper certification, some local distributors are disabling Wi-Fi functionality. Check with your dealer before purchasing a Yun if you believe you may live in such a country. If you wish to disable Wi-Fi, run this sketch. The Yun distinguishes itself from other Arduino boards by its ability to communicate with the Linux distribution onboard, offering a powerful networked computer with the ease of an Arduino. In addition to Linux commands like the cURL, you can write your own shell and python scripts for robust interactions. The Yun is similar to the Leonardo with the ATmega32u4, except that it has Linux on board. (has built-in USB communication, eliminating the need for a secondary processor). The power supply system provides 5V on AREF and the layout has been modified, adding two holes for USB signals and two holes for GP6 and GPIO13(LED2). Overall even though the price is not right for the team, we can not deny the fact that the microcontroller has more resources online than the Arduino Uno and the Arduino Micro.

3.3 Wireless Communication Technologies

Wireless communication is one of the most important contributions to mankind. Wireless Communication is useful because it transmits information over a distance without the use of wires and cables. One of the benefits of wireless communication is that the signals can be transmitted distances from a few feet to thousands of miles. Almost every device nowadays has some form of wireless communication for example smartphones, GPS, laptops, and radio. There are multiple different types of wireless communication for example ZigBee, Wi-Fi and Bluetooth.

3.3.1 Wi-Fi

Wireless Fidelity (Wi-Fi) allows users to access the internet when connected to an access point. The U.S. Federal Communications Commission came to a ruling in 1985, which released for unlicensed use by any user the radio spectrum bands at 900 Megahertz (MHz), along with 2.4 and 5.8 Gigahertz (GHz), this ruling resulted in the first step in the origin of Wi-Fi Technology. Early on there were no common standards, so major advances were not made, but in 1997 the Institute of Electrical and Electronics Engineers (IEEE) approved a new common standard called 802.11. The Wireless Ethernet Compatibility Alliance was formed two years later to promote new wireless standards, this organization named the new technology Wi-Fi. [6]

In today's day and age, Wi-Fi is a big part of the average Americans life, most households use Wi-Fi and Wi-Fi connected devices, because of this fact many devices are developed to use Wi-Fi technology.

Wi-Fi has many benefits, for example, the interoperability of Wi-Fi is very important as that allows many different device to communicate. Wi-Fi also has a large area of effect, especially when in use of a user's home, the range can also easily be extended, so if a device is separated from the access point by several walls or floor a better router or Wi-Fi extender can easily solve this problem.
Wi-Fi does have some limitations or problems as well, for example, the network is only as secure as the network administrator makes it. Another limitation is Wi-Fi is normally connected to the user's power, so if there is a power outage, the devices connected will lose access to any services which required Wi-Fi.

3.3.2 Bluetooth

Originating in 1994 as a replacement for cable technology by the cell phone manufacturer Ericsson, Bluetooth uses radio technology to provide low cost, low power and short range wireless communication. Currently many devices implement the use of Bluetooth technology, such as smartphones, speakers and even keyboards for a computer. In early 1998, the Bluetooth Special Interest Group (SIG) was formed by Ericsson along with several companies such as International Business Machines Corporation (IBM) and Intel Corporation. The members of SIG could make advancement which ultimately resulted in open standards, letting Bluetooth be more compatible in the current and progressing marketplace. [7]

Instead of using cables or wires, Bluetooth uses radio waves to connect to devices such as headphones. These devices contain a chip with, on that chip is software and a Bluetooth radio which enables the connection. Bluetooth devices communicate through a short ranged, ad hoc network called Piconets. When a Piconets network is connected, the role of master is taken by one of the devices, while all other devices will have a role of slave. [8]

The benefits of Bluetooth, range from ease of use to low energy. A popular use for Bluetooth is for wireless audio, such as headsets or connectivity in cars. Bluetooth is popular for streaming because it has a special version called basic rate/enhanced data (BR/EDR) which has been optimized for power efficiency and to send a high quality steady stream of data. Another benefit of Bluetooth is its low energy functionality. Since Bluetooth uses such a small amount of energy developers can create smaller sensors, without having to waste space on batteries. [8]

One of the major drawback of Bluetooth is its short range, because of this limitation many devices disconnect frequently. Although, the Piconets are connected automatically and dynamically, so once the devices are back in range they will automatically be connected.

3.3.3 ZigBee

Many everyday wireless IoT devices use a wireless language called ZigBee to connect to each other. By passing data through a mesh network using intermediate devices to reach far devices, ZigBee can achieve transmitting data long distances. ZigBee addresses the issue of device-to-device communication, and is the only standards-based wireless technology designed for this issue. Founded in 2002 ZigBee is a global alliance of companies.

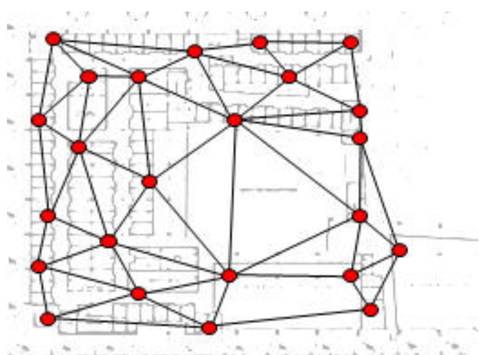
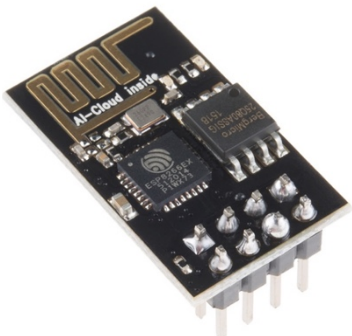


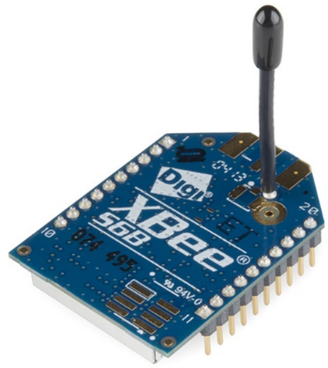
Figure 4 - Example of ZigBee Meshing Network

There are many Benefits to using ZigBee, for example, it consumes a small amount of power, this allows for devices which use ZigBee to be battery operated and have the potential to operate for several years. By using several different security mechanisms ZigBee is secure. It is also powerful and reliable, ZigBee eliminates the possibility of a single point in the mesh failing by using a multi-hop mesh network. Companies such as Philips use ZigBee for their Hue System. [9]

3.4 Wi-Fi Modules

The Smart Hub Light System will communicate with the light bulbs and the software interfaces using a Wi-Fi module. There are many different types of Wi-Fi modules that are available in the market today. For this project, the team will go through a list of the different Wi-Fi modules to determine which module fits the project's goals. Below are some of the images of the Wi-Fi Card which will be discussed.





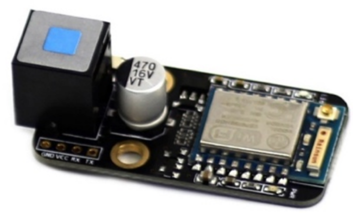


Figure 5A - ESP8266 *Figure 5B - XBEE* *Figure 5C - ME*

Figure 5D – ESP-07 *Figure 5E – ESP-WROOM-32*

3.4.1 ESP8266 Wi-Fi Module

The first module that the group is looking at is the ESP8266 Wi-Fi module. This module only costs $6.95 and is very small and compact. This will become a key factor in the PCB design for the smart light hub system because the team is trying to design a device that is not too bulky. It is integrated with a TCP/IP protocol stack that can give any microcontroller access to a wireless network. One of the key things with this Wi-Fi module is that it is capable of hosting or offloading wireless network function from another application processor. Essentially with this project, this module would basically make the software engineers portion of this project easier because the module can easily connect to a wireless network. One thing to note with this module is that because of the size of the module, if you were to power it from the microcontroller's power supply, you would essentially destroy the microcontroller. To prevent this, a converter will be needed to shift the amount of voltage that the microcontroller provides. One key feature that made the team consider this module was that it can easily be integrated with sensors through its GPIO with a minute amount loading during runtime. One last key feature for this module is that all the documentation and support can be found on online forums and on the developer's website. A figure for this Wi-Fi module can be found below.

3.4.2 TI SimpleLink CC3000 Wi-Fi Module

The next module to be considered is the TI SimpleLink CC3000 Wi-Fi module. This module is a self-contained wireless network processor that basically simplifies the implementation of connecting to a wireless network. The only issue in selecting this Wi-Fi module is that this module is very limited to certain microcontrollers. Specifically, this module is only compatible with only TI microcontrollers. This would be a huge setback for the team because it limits the selection of which microcontrollers that we can choose from. Looking at the cost of this module, it would cost us $33.39. Overall when comparing this module to the ESP8266, the price difference is insanely huge. Essentially, we would be paying $27 more for this module to get the same functionality. Maybe the only thing that would be different from the two is the speed of the Wi-Fi modules.

3.4.3 ESP-01 Wi-Fi Shield

The next module that we decided to consider was the ESP-01 Wi-Fi Shield. This module is very similar to the ESP8266 Wi-Fi module. The reason why it is very similar to this module is because the module is based off of the ESP8266 chipset. The module cannot be connected directly to a typical Arduino because a typical Arduino outputs 5V. This module can only sustain a 3.3V output. Because of this a mode pin will need to be set so that this module can operate correctly. So, a drawback for this module is that it does not include the Wi-Fi module. So essentially, we would have to pay separately for both the Wi-Fi module and the Wi-Fi shield which would be pointless for us because why would we want to allocate more money towards two different Wi-Fi modules when we can pay for just for one Wi-Fi module. If we were to choose this design, the cost of the Wi-Fi shield is $10.45. The good news is that the ESP8266 can be connected to this Wi-Fi module, but still we would be spending almost $16. This would be highly ineffective for us because we are trying to keep the cost of this project to a minimum of $700.

3.4.4 Arduino Uno Wi-Fi Microcontroller

With the next module, it encompasses a Wi-Fi module into a microcontroller. This design is unique because it takes two chips that we are looking for and combines them into one chip. The overall cost for this microcontroller is $37.52. The board that this microcontroller is based off of is the ATmega328P. Included in this microcontroller are fourteen digital input or digital output pins and a self-contained SoC with an integrated TCP/IP protocol stack. The module that is integrated into this microcontroller is the ESP8266 Wi-Fi module. So, after going through three modules, we are noticing an overall trend of the Wi-Fi modules. The trend is that each of the previous Wi-Fi modules are based off of the ESP8266 Wi-Fi module. The operating voltage for this microcontroller is 5V and the flash memory for this microcontroller is 32KB. Included on the microcontroller board are 6 analog pins and 2KB SRAM. So overall choosing this microcontroller would be a good option, but in terms of what we are trying to do with this project, we feel that we should have the microcontroller and Wi-Fi modules separated. The reason for this is if we are connecting about 10 LEDs, we feel that this might overload the signal being sent to the Wi-Fi card, which is why we are suggesting to using multiple Wi-Fi cards.

3.4.5 Intel Edison and Mini Breakout Kit

The next Wi-Fi module/microcontroller is the Intel Edison And Mini Breakout Kit. This module is unique because it utilizes an Intel Atom processor with an integrated Wi-Fi module inside the breakout kit. The power utilized by this module is approximately 1.8 volts. The module itself is small and compact and delivers a great performance, durability and a broad range of inputs and outputs. A unique feature about this module is that it includes a battery recharger. This is the first module that we have seen that can work without being connected to another microcontroller. The cost for this breakout module is $74.95. For what is included with this kit, the price is reasonable. However, for what we are trying to accomplish with this project, we feel that this price is highly unnecessary because of the practical applications that are needed for our project.

3.4.6 XBee Wi-Fi Module

The next Wi-Fi module that we considered was the XBee Wi-Fi module. This module consists of an XBee Wi-Fi module with a wired antenna. This module provides simple serial to IEEE 802.11 connectivity. The XBee WiFi creates new wireless opportunities for energy management, process and factory automation, wireless sensor networks, and intelligent asset management. The XBee WiFi module is designed to communicate with access points in existing 802.11 infrastructures. Developers can use AT and API commands for advanced configuration options. The cost for this device is roughly around $43.95. While this device does provide more flexibility for us, we feel that the cost of this module is too high. In terms of our project, we feel that the serial communication might cause errors in the overall software development and speed of the device because serial communication is much slower than communication over Wi-Fi directly.

3.4.7 EMW3162 Wi-Fi Shield

The next module that we are considering is the EMW3162 Wi-Fi shield. This particular Wi-Fi is only compatible with Arduino and Nucleo microcontrollers. Essentially, this Wi-Fi shield costs only $19.99 and includes both the Wi-Fi module and the shield. Since this module is only compatible with Arduino microcontrollers, it will make it a hard decision for us to choose which microcontroller we would want to use because if we choose to use this Wi-Fi module, then this would limit us to only consider Arduino microcontrollers. The good thing about this module is that it supports EasyLink fast matching, which means that it would allow us to connect our smartphone device to the network by using the EMW3162 Wi-Fi application. This module consists of sixteen different input and output pins, which is a good thing for us because the more input or output pins that we have means that we can connect a lot of sensors or LEDs to the Wi-Fi shield.

3.4.8 ME Wi-Fi Module

The next Wi-Fi module is the Me Wi-Fi Module. This Wi-Fi module is capable of providing communication over a long distance. This module also contains an Arduino Library which would make the software side of the Smart Light Hub system easy for the team if we decide to choose an Arduino microcontroller. The module is rated at a minimum voltage of 6 volts and a maximum of 12 volts. The module is rated at a current of 1.5 amps. The cost for this module is $19.99. So overall, we would have to agree that while this price is reasonable, we feel that we can still find a cheaper Wi-Fi module that can perform the goals that our team wants.

3.4.9 TinyShield Wi-Fi

The next Wi-Fi module is the TinyShield Wi-Fi module. This module allows users to connect multiple sensors and microcontrollers to a wireless network. It is based on the Texas Instruments CC3000 Wi-Fi module and supports 802.11b and 802.11g. It is also one of the first modules that we have seen that allows us to implement a security mode on our wireless network. This module also has a built-in TCP/IP Stack and supports up to four concurrent sockets. One thing with this module is that it contains an antenna that is supported by the Federal Communication Commission (FCC). This module includes level shifters and local power supply to ensure proper and safe operation of the Wi-Fi module. With this module, it does not transfer data using the regular serial protocol, instead it uses a SPI interface to allow the transfer of data bits. Using the SPI interface means that there will be a faster transfer of data. One drawback for this module is that it cannot act as its own access point, which is not necessarily a bad thing for us. For the scope of our project, we need a Wi-Fi module that can connect to a smartphone device via a wireless network. The sole purpose for a Wi-Fi card for our project is to provide communication between the smartphone and the light bulbs or LEDs. The cost for this Wi-Fi module is $59.95. If we choose to use this Wi-Fi module, then we would be able to provide a lot of functionality for our project. The only problem that we can see from this is that the cost of the module is too high.

3.4.10 RTL8710 Wi-Fi Wireless Transceiver Module SOC

Another Wi-Fi module that we were looking into was the RTL8710 Wi-Fi module. This module is specifically for the Arduino microcontroller. The module itself has its own processor called ARM-CM3. The memory on this module is 44 kilobytes and the flash memory for this module is one Megabyte. The rated voltage for this module is 3.3 volts and the rated current for this module is 80 milliamps. Overall this module would cost us about $3.26. So for us, the price is extremely reasonable, but the only problem is that it would limit us to having to choose only one microcontroller. For this module, it is only compatible with the Arduino microcontroller which means that it limits our range of which microcontrollers we can choose from. Another issue we could encounter for this module is that because the cost is very low, the quality of the module might not be good enough for what our project is trying to accomplish.

3.4.11 ESP-07S Wi-Fi Transceiver Module

The final Wi-Fi module that we are looking into is the ESP-07S. This Wi-Fi module is a wireless serial transceiver module that is based upon the ESP8266 module. With this module, it utilizes a filter circuit and reduces power being used by the overall Smart Light Hub System. This module is widely used in networking and has been applied to most smart home projects if it is connected to a wireless network or router. The key features that this module can be used for are remote monitoring of home appliances, bedroom temperature and humidity and controlling home appliances by using a cellular device. So overall the cost for this module is $4.66. The rated voltage for this module is around 3 to 3.6 volts and the rated current for this module is around 200 milliamps. This module contains a 4 Megabyte on-board flash memory and is compatible with the 802.11b wireless standard, the 802.11g wireless standard and the 802.11n wireless standard. With this module, the one thing that caught our attention was the fact that this module is the only module that listed that it worked with home appliances and with a smartphone device. The good thing about this module is that it is very easy to program with any microcontroller meaning that we can choose any microcontroller that we want to use if we were to select this module.

3.5 Bluetooth Modules

Figure 6A - RN42

Figure 6B - PAN1721

3.5.1 ESP-WROOM-32 Wi-Fi 802.11 & Bluetooth Module

The first Bluetooth module that our team decided to look at was the ESP-WROOM-32 Wi-Fi & Bluetooth Module. This module is an extremely powerful module in a sense that it incorporates both Wi-Fi and Bluetooth into a very small and compact device. This chip comes fully equipped with 2 CPU cores that can be controlled and powered individually. The clock speed for this device can be adjusted between 80 Megahertz to 240 Megahertz. The CPU can be powered off in order to use the low-power co-processor to constantly monitor peripherals for changes or crossing of thresholds. This module is capable of running low-power sensor networks, voice encoding, MP3 decoding or music streaming. With the Bluetooth aspect, this module can connect users to their phone or broadcast low energy beacons for its detection. This chips only uses 5 microamps and can support data rates of up to 150 Megabits. This module only costs $3.95. In terms of the price of this module, we feel that this is extremely reasonable to pay and that this module comes with both Bluetooth and Wi-Fi compatibility as well as compatibility with the Arduino interface.

3.5.2 BLE112-A-V1

[10]The Bluegiga's BLE112 Bluetooth Smart Modules are ideal for low-power sensors and accessories. They have all the features required for a Bluetooth Smart application, including Bluetooth radio, software stack, and GATT-based profiles. The Smart modules can also host end-user applications which means that no external microcontroller is required in size or price constrained devices. Also, it has flexible hardware interface to connect to different peripherals and sensors and can be powered directly from a standard 3v coin cell battery or a pair of AAA batteries. In the lowest power mode it only consumes around 500nA and can wake up within a few hundred microseconds. One feature of this module is that it contains a fully integrated Bluetooth Smart Solution and can be integrated with Bluetooth, Radio, microcontroller and software stack. The data for this module can be stored in the flash memory along with the settings. The price for this module is $11.89. With this module we would be paying three times as much as the previous Bluetooth module and we would not be getting the Wi-Fi compatibility as the previous module included.

3.5.3 BT832- Bluetooth BLE 5 Module

The next Bluetooth module that we are looking into is the BT832- Bluetooth BLE 5 Module. This module is an NFC (Near-Field-Communication) module that operates using a Nordic nRF52832 and includes an integrated PCB trace antenna. The module itself is very compact and has hardware that meets the Bluetooth 5.0 specifications. This module includes sixteen pins that are perfect for applications requiring limited numbers of GPIOs. The 24 Land Grid Array(LGA) pins that provide access to all of the nRF52832 GPIO pins. This module is capable of operating in host mode or in stand-alone mode. The way that stand-alone mode works for this module is that the stand-alone mode downloads firmware directly to the flash memory of the module and the host mode connects a device to a host using UART, which utilizes AT commands. This module comes equipped with a 512 Kilobyte flash memory, 64 Kilobytes of RAM and an embedded 2.4 Gigahertz multi-protocol transceiver. The module utilizes the Cortex M4F processor as well as an AES HW encryption. This module is ideal for IoT (Internet-of-Things) applications and the built-in NFC can be used to easily and securely pair the module to other BLE(Bluetooth Low Energy) devices. The module is also capable of passing credentials from a smart phone or tablet to the module. This module also comes equipped with a built-in Temperature sensor which monitors the module's operating conditions. Since this module is equipped with an on-module memory and processor, it allows for the development of the most demanding IoT applications. Since this module contains the Nordic nRF5282 which is compatible with the Apple Homekit applications. The cost of this device is only $5.50. So with this device, it can be seen that it comes with a lot of features that are capable of meeting our project goals.The only issue that we would see is that it is a bit more than the first Bluetooth module and this module does not come with a Wi-Fi compatibility like the first module in this section. But overall we will decide which module we will go with later on in the coming sections.

3.5.4 RN4020-V/RM-Microchip Technology

[11]The RN4020 is a Bluetooth smart module for anyone who wants to easily add low-power regulatory approved wireless capability to their products. The RN4020 have a turnkey solution with a complete software stack, and RF components on board. The RN4020 includes an onboard antenna and is interfaced and configured via a simple ASCII command interface over UART. The RN4020 supports all standard Bluetooth SIG profiles, and microchip's Low-Energy data profile for custom serial data transfer. It also allows for anyone to script to set the RN4020 up for standalone operation where any one of the analog or digital I/Os can be monitored and the values can be transmitted over wireless without the use of a host MCU or processor. The size of the RN4020 is 11.5 × 19.5 × 2.5 mm size, enables ease of integration. With 7 dBm transmit power, the RN4020 can achieve a range of around 100 meters and has a sleep mode of less than 1 uA, and designed to be powered from a single coin cell battery. The cost for this Bluetooth card is around $9 which is reasonable considering the size and efficiency of the card.
Features of RN4020:

- Fully certified Bluetooth version 4.1 module
- On-board embedded Bluetooth low energy stack
- Multiple IOs for control and status
- GAP, GATT, SM, L2CAP and integrated public profiles
- Field upgradeable via the UART interface or over the air
- 64 KB internal serial Flash
- Environmentally friendly, RoHS compliant
- Bluetooth SIG and worldwide regulatory certification

3.5.5 RN42 Bluetooth to Serial Module

The BlueSMiRF Silver is the lastest Bluetooth wireless cable replacement from Sparkfun Electronics. This version uses the RN-42 module with a bit less range than the RN-41 module. Any serial stream from 2400 to 115200bps can be passed seamlessly from the computer to the target. The unit can be powered from a 3.3v to a 6v for each battery attachment. The Bluetooth card uses the v6.15 firmware. It is FCC approved class 2

Bluetooth radio modem. The size of the card is small with .15x.6x1.9 inches. The link is very robust in integrity and has a transmission distance of 18 meters. The frequency at which the card opperates is between 2.402 and 2.48 GHz. The price of the BlueSMiRF Silver is $25 which is on the higher end of prices.

3.5.6 BC832 Low Energy Bluetooth Module

BC832 - Low Energy Bluetooth Module [12]The BC832 is a Bluetooth Low Energy 4.2 with NFC module that uses the Nordic nRF528 SoC has an integrated chip antenna. It come with fully equipped with 16 pins, which is great for applications that require a limited number of GPIOs. There is also 24 LGA pins that provide access to all the nRF52832 GPIO pins. This Bluetooth module comes in a compact size of 7.8 x 8.8 x 1.2mm. The BC832 module can either operate in standalone mode or host mode. Host mode connects the device to a host via UART and utilizes AT commands. Standalone mode downloads firmware to the flash memory. Pending FCC ID and IC (Industrial Canada) ID certification, this Bluetooth module has 512 KB flash, 64 KB RAM, and an embedded 2.4 GHz multi-protocol transceiver. The included Cortex M4F processor utilizes AES HW encryption. The price for the BC832 is $5.50 which is one of the lower priced Bluetooth modules. This card would be good for the project because of the size and price of the card.

3.5.7 RN42SM-I/RM Microchip Technology

The next Bluetooth module that will be discussed is the RN42SM-I/RM Microchip. The RN42 is a small form factor, low power, Class 2 Bluetooth Radio for designers who want to add wireless capability to their products. The RN42 supports multiple interface protocols, is simple to design in, and is fully certified, making it a complete embedded Bluetooth solution. The RN42 is functionally compatible with the RN41 and with its high-performance PCB trace antenna and support for the Bluetooth EDR. The RN42 is capable of transferring data at a rate of 3 Megabits per second for a maximum distance of twenty meters. This module comes with an on-board Bluetooth stack, which means that there is no host processor required when using this module. One key feature about this Bluetooth module is that this module can support Bluetooth data links to the Apple iPhone, the apple iPad and the apple iPod Touch. This module also includes secure communication between devices by using a 128 bit encryption. This module includes 11 GPIO pins and contains 35 pins. The minimum voltage that this module can operate at is 3 Volts and the maximum voltage that this module can operate at is 3.6 Volts. The minimum operating [13]temperature for this device is -40 degrees Celsius and the maximum operating temperature for this device is 85 degrees Celsius. One interesting feature with this module is that the antenna is optional. This module can be purchased without the antenna for applications that require the use of an external antenna. The cost of this module is $11 . While the cost of this module is reasonable, a lot of the other Bluetooth modules include more features and cost significantly less. A figure for this module can be found below.

3.5.8. Cyble-022001-00 BLE Module

The next module that will be discussed stems from the Cypress Semiconductor Group. This module is a fully certified module that supports Bluetooth Low Energy (BLE) wireless communication. This module is a turnkey solution that includes onboard crystal oscillators, a chip antenna, passive components and Cypress PRoC™ BLE. This module supports a number of peripheral functions such as Analog and Digital communication, timers, counters, and PWM. This module also contains a few serial protocols, such as IC, UART, SPI through its programmable architecture. This module includes a royalty-free BLE stack compatible with Bluetooth 4.1. This module consists of 16 GPIO Pins in a small compact package. The temperature rating for this module is between -40 degrees Celsius to 85 degrees Celsius. This module consists of a 32-bit processor with a single-cycle 32-bit multiplier that operates up to 48 Megahertz per second. This module also includes a 128 Kilobyte Flash memory and 16 Kilobyte SRAM memory. The overall operating voltage for this module is between 1.8 Volts and 4.5 Volts. The cost for this module is $12. While this module is around the same price as the previous module, our team feels that there are a lot of other modules listed in this section that are far cheaper and capable of accomplishing the goal of this project.

3.5.9 ENW-89835A3KF PAN1721 Class 2 Bluetooth Module

The final module that will be discussed in this section is the PAN1721 Bluetooth module. PAN1720/21 Bluetooth low energy single-mode module has been specially developed for applications which communicate with dual or single mode Bluetooth low energy devices like mobile phones, PDA´s, Laptops etc. It is very easy to expand your personal area network with this module, using existing gateways. The included Bluetooth low energy stack is currently supporting the proximity and battery profile. The user specific application can be written on top of the Bluetooth Stack. The communication between stack and application is handled via vendor specific HCI-commands. The PAN1720(21)-Module is manufactured in a very small 15.6 x 8.7 x 1.9 mm^3 SMD package with shielded case and will be qualified according to the Bluetooth 4.0 standard. This module is capable of having a data transfer rate of up to 1 Megabit per second. The module also comes with 256 Kilobytes of Flash memory and 8 Kilobytes of random access memory (RAM). The overall cost of this module is $10.91. Looking at all of the Bluetooth modules that have been discussed, it can be seen that while this module comes with the same features as other modules, the overall cost of this module is relatively larger than other modules. A figure of this module can be found below.

3.6 Comparison of Microcontroller

Now that we have discussed about the different types of microcontrollers, Wi-Fi modules and Bluetooth modules, the next step is to compare each of these modules and determine which one would be the most beneficial to the design of the Smart Hub Light System. In terms of what was discussed in the Microcontroller section, there were 13 different microcontrollers discussed. Out of those 13 microcontrollers, the number has been narrowed down to the top five microcontrollers. The five microcontrollers that the team is considering are the Arduino Micro, Arduino Uno, Teensy 2.0, Arduino Mega and TI MSP430G2553. The TI MSP430FG4618 was not considered because the overall cost of this microcontroller was $117.92. The Teensy ++2.0, 3.0 and 3.1 were not considered because while the RAM and flash memory were larger than the Teensy 2.0, the team felt that the Teensy 2.0 was more than capable of handling the task of controlling the LEDs..

3.6.1 Comparison of the Microcontroller Versus Power Consumption

In this section, five microcontrollers will be considered in terms of the Power being consumed from those microcontrollers. A table displaying the power consumption of each of the five microcontrollers can be found below.

Table 2 - Microcontroller Comparison of Power Consumption

Microcontroller	Unit Price	Flash Memory	Power Consumed	GPIO COunt
Arduino Micro	$24.95	32 KB	1 mW	14
Arduino Uno	$24.95	256 KB		54
Arduino Mega	$45.95	32 KB	2 mW	20
Teensy 2.0	$16.00	32 KB	4.5 mW	25
TI MSP430G2553	$9.99	16 KB	.828 mW	16

From the table, the power consumption was calculated based on multiplying the operating voltage by the operating DC current. This yielded the total power being consumed by each of the five microcontrollers. In the table, it can be seen that the MSP430 is the microcontroller with the least amount of power being used. The Arduino Micro and Uno both consume the same amount of power at 1 mW. The Teensy 2.0 consumes the most power at 4.5 mW. While consuming the least amount of power is a goal for our project, the team will also look at the cost of each of these microcontrollers, as well as memory size, GPIOs and Clock Frequency.

3.6.2 Comparison of Microcontroller Versus Cost

Cost is one of the most important issues when it comes to designing a Smart Hub Light System. Our team wants to make sure that we can utilize the most effective microcontroller while keeping the costs low. In terms of presenting the Smart Hub Light System to consumers, the overall cost for this needs to be low. Overall looking at the prices in the table, to determine the system price increase, the least costly of the five microcontrollers were used to determine the price increase of the system. To calculate that, it would be the difference between the cost of one microcontroller and the cost of the MSP430 divided by the cost of the MSP430. For the purpose of the project and the budget of this project, the team feels that the prices of the Teensy 2.0, Arduino Micro and Arduino Uno are reasonable. Besides the cost, there are still the factors of the memory size, GPIO pins, and clock frequency.

3.6.3 Comparison of the Microcontroller Versus Memory Size

The next comparison for the five microcontrollers will be the memory size of each microcontroller. The reason why this comparison is needed because the team wants a microcontroller that will be fast enough to process all of the data that is being transferred from the cellular device to the microcontroller. That data will then be sent to the Wi-Fi or Bluetooth modules which will then turn on the LEDs. Looking at the table above, it can be seen that the Arduino Mega has the most memory size. However, in the last section, the cost of the Arduino Mega was the most expensive out of the five microcontrollers. The TI MSP430 contains the least amount of memory size which is not a bad thing, but in terms of how many processes the microcontroller will have for this project, the TI MSP430 might be too slow to handle these processes. Looking at the Arduino Micro and Arduino Uno, the flash memory is about the same, but the RAM memory differs by 0.5 Kilobyte. The Teensy 2.0 and the Arduino Micro both have the same memory specifications but the cost of the Teensy 2.0 differs from the Arduino Micro by approximately $9. Overall the comparison of the memory size, cost and power consumption will lead our team to a decision for the microcontroller, but there are still two comparisons lefts, the comparison of the GPIO pins and the comparison of the Clock Frequency.

3.6.4 Comparison of the Microcontroller Versus GPIO Pins

The next comparison that will be looked at is the number of General Purpose Input/Output (GPIO) Pins. The reason why the team is considering this is because of the amount of Wi-Fi or Bluetooth modules that needs to be connected to the microcontroller. Not only that but the team also has LEDs that they want to power from the microcontroller and the team wants to be able to use the microcontroller to control a pattern from the LEDs. Comparing the five microcontrollers listed in the table above, it can be seen that the Arduino Mega has the most GPIO Pins. At the same time, going back to the cost and power consumption sections, the Arduino Mega costs the most out of the five microcontrollers but does not consume the most power out of the microcontrollers. Surprisingly, the Teensy 2.0 has the second most GPIO pins and cost the second least out of the five microcontrollers. The only issue with the Teensy 2.0 microcontroller is that it consumes the most power. Comparing the Arduino Micro and Arduino Uno, in terms of the GPIO pins, the Arduino Micro contains more than the Arduino Uno. Both of these microcontrollers cost the same, and consume the same amount of power. In terms of the memory size however, the Arduino Micro has more RAM than the Arduino Uno. The last comparison that will be in this section is the comparison of the clock frequency of each of the five microcontrollers.

3.6.5 Comparison of the Microcontroller Versus Clock Frequency

The last comparison of the microcontroller will be the in terms of the Clock Frequency. The reason for this comparison is because the Clock Frequency will determine how fast the microcontroller can process data from the cellular device and send it out to the Wi-Fi or Bluetooth Modules. Overall looking at the table for the Clock frequency for each of the microcontrollers, it can be seen that they all have the same clock frequency. While the comparison might not help to determine the best microcontroller, it did outline the clock speeds of each of the microcontroller which allows the team to gauge the other four comparisons more heavily for the microcontroller.

3.6.6 Microcontroller Choice: Arduino Uno

So after analyzing all of the tables and comparing everything, the team has decided to use the Arduino Uno microcontroller. The reason as to why this microcontroller was selected was because even though the Arduino Micro has almost the same exact capabilities and costs the same amount, the Arduino Uno is more user friendly when it comes to the software side of this project. The reason as to why the TI MSP430 was not selected is because while the clock frequency was the same for all microcontrollers, the TI MSP430 included only 16 KB of flash memory while the Arduino Uno has 32 KB of flash memory. That amount of memory in the Arduino Uno means that the overall speed of this module will be faster than the TI MSP430. The reason as to why the Teensy 2.0 was not selected as the primary microcontroller is because in terms of clock frequency, cost, memory size and GPIO the Teensy was the more favored choice. However when it came down to the amount of power that the Teensy 2.0 consumed versus the Arduino Uno, the Teensy 2.0 consumed about 4.5 mW, while the Arduino only consumed 1 mW. Not only that, but the Teensy 2.0 consumed the most power out of all five of the microcontroller which made it a big factor for the team trying to conserve on power for the overall Smart Hub Light System. The reason as to why the Arduino Mega was not selected as the primary microcontroller is because while the Arduino Mega has the most GPIO pins and memory, the microcontroller consumes the second most power out of the five microcontrollers. Not only that, but the overall cost for this microcontroller is the most out of the five microcontrollers that are listed in **Table 2** above. That is the reason why the team decided to not to go with the Arduino Mega. The team also chose to use the Arduino Uno because the amount of resources that are available to the team in terms of forums and documentation. The Teensy 2.0 and TI MSP430 do have forums as well, but the response times for users to respond were not as efficient to the team as the response times for the users from the Arduino Forum. One thing to note about this microcontroller is that while it does cost almost 150% more than the TI MSP430, the team decided that the cost was not going to be an issue in terms of the microcontroller. The team felt that the cost for this microcontroller was reasonable and not only that, but there were other websites that were selling the same Arduino Uno at a cheaper price. So the team is looking into that as of now, but overall the team is content with their decision to use the Arduino Uno.

3.7 Comparison of the Wi-Fi and Bluetooth Modules

In this section, the team will be comparing the different Bluetooth and Wi-Fi modules that were presented in the previous sections above. The team has narrowed down both the Wi-Fi and Bluetooth modules to five Bluetooth modules and five Wi-Fi modules. In the first section, the team will be discussing the five different Bluetooth modules followed by the five different Wi-Fi modules. The team will then determine which of the wireless technology they would like to proceed with. After that, the team will select the module that will be implemented in the Smart Hub Light System.

3.7.1 Comparison of the Bluetooth Modules

In this section, the team has narrowed down the Bluetooth modules to five Bluetooth modules. These Bluetooth modules are the ESP-WROOM-32, BT832, RN4020, BC832, and the Cyble-022001-00. The reason as to why the BLE112 was eliminated was because the overall cost was too high and the overall features compared to the price was not worth it to the team. The reason as to why the RN42 was eliminated was because the overall cost for this module was at $25 which was more higher than most of the Bluetooth modules that were presented above. The reason as to why the RN42SM-I was eliminated was because the team felt that while this module only costs $11, the features that came with this model were not sufficient enough for the team to consider this Bluetooth module. The reason as to why the PAN1721 was eliminated was because the overall cost of this module compared to the other five modules was slightly high and this module did not include as many features as the five Bluetooth modules selected. Looking at the five Bluetooth modules, these will be compared to the overall cost of the modules, the amount of flash memory included, the number of GPIO pins, power consumption and range of the Bluetooth module.

3.7.1.1 Comparison of the Bluetooth Modules Versus Cost

The first comparison for the Bluetooth modules will be the overall cost of these modules. The cost of these modules play a big role in the Smart Hub Light System because the budget has already been established. Overall the comparison of the Bluetooth modules versus the cost can be found in the table below.

Table 3 - Comparison of Bluetooth Modules and Cost

Bluetooth Modules	Unit Price	Power Consumption (mW)	Flash Memory	GPIO Pin Count
ESP-WROOM-32 Wi-Fi 802.11 & Bluetooth Module	$3.95	8.00 mW	16 MB (External)	0
BT832 Bluetooth BLE 5 Module	$5.00	9.18 mW	512 KB	32

RN4020-V/RM Microchip Technology	$8.83	4.5 mW	64KB	10
BC832 Low Energy Bluetooth	$9.12	9.18 mW	512 KB	32
Cyble-022001-00 BLE Module	$6.70	.208 mW	128 KB	16

After looking at the costs in the table, it can be seen that least expensive Bluetooth module is the ESP-WROOM-32 module. Using the System cost from the ESP-WROOM-32 module, the team was able to determine the overall price increase for each of the other modules. With the BT832 module, the overall price increase is not relatively bad. The price only increases by 27.2%. With the RN4020 and the BC832 modules however, the price increase for both of these modules is over 100% which is not a good thing in the overall budget for the Smart Hub Light System. With the last Bluetooth module, the Cyble-022001-00 BLE module only has a system price increase of approximately 71%. While the price of this module is not bad, a price increase of 71% is still high in terms of the budget for the Smart Hub Light System. There are still four other comparisons that need to be completed for the Bluetooth module. The next comparison is based on the amount of flash memory that comes with each of the modules.

3.7.1.2 Comparison of the Bluetooth Modules Versus Memory Size

The next comparison for the Bluetooth Modules will be based upon the memory size. The reason as to why this is important is because for all of the data that the modules will have to process for the Smart Hub Light System. The module will need to process the data coming from the cellular device and send the data back to the microcontroller to turn on the LEDs. After looking at the table above, it can be seen that the ESP-WROOM-32 Bluetooth module has the most memory out of the five Bluetooth modules listed. However after looking at the documentation for that module, the memory is only external memory meaning that there is no internal memory that comes with this Bluetooth modules. So comparing the table to the internal memory that comes with the other four Bluetooth modules, both the BT832 and BC832 Bluetooth modules contain the most flash memory at the same time, the system price increase for the BC232 is over 100%, while the price increase for the BT232 is only 27%. With the RN4020 Bluetooth module, it does not include any RAM memory. The module only contains 64 kilobytes of flash memory. Finally with the Cyble 022001-00 Bluetooth module contains 128 kilobytes of flash memory and 16 kilobytes of RAM memory. While that is not bad, the overall cost for this model increases the system price by 70%. While memory size is an important factor for the Smart Hub Light System, it is not the only thing that the team will consider. The next item that the team will consider is the number of GPIO pins that are included with each of the Bluetooth modules.

3.7.1.3 Comparison of Bluetooth Modules Versus GPIO Pins

The next comparison for the Bluetooth modules will be the number of GPIO (General Purpose Input/Output) pins. The reason why the team wanted to do this comparison is because of the number of components that are going to be connected to the Bluetooth modules. Overall looking at the table above, the ESP-WROOM-32 includes zero GPIO pins which means that in order for this module to work for the scope of the team's project, a card reader or a Bluetooth card module will need to be utilized. This is a bad thing because then this means that in addition to purchasing this Bluetooth module, the team will also need to purchase a Bluetooth Card Reader. Not only that , but it would mean that the team would have to modify the design of the Smart Hub Light System. Looking at the other four Bluetooth modules, it can be seen that both the BT832 and BC832 Bluetooth modules include the most GPIO pins. However, in the case of the cost of the Bluetooth modules, the BT232 is by far cheaper than the BC232. In the case of the RN4020 Bluetooth module, it only includes 10 GPIO pins. While this is not a bad thing, looking at the other tables above, the overall cost for the module is too high and the overall amount of memory included is not that much. In the case of the Cyble 022001-00 Bluetooth module, it includes 16 GPIO pins and has a decent amount of memory internally, however the overall cost of the system would increase by 71% if this module was implemented in the Smart Hub Light System. The next comparison that will be covered is the amount of power that each of the modules consumes.

3.7.1.4 Comparison of the Bluetooth Modules Versus Power Consumption

The next comparison that will be covered in this section is the comparison of the Bluetooth modules with the amount of power being consumed. Power Consumption is one of the most important factors in developing the Smart Hub Light System. The team wants to ensure that the modules that they utilize in this project does not consume a lot of power. Looking at the table above, the power consumption for each of the microcontrollers were calculated based on the operating voltage and the operating current. To calculate the power consumed, it involves the product of the operating voltage multiplied by the operating current. Looking at the table above, the BT832 and the BC832 consumes the most power out of the five Bluetooth modules. However, the ESP-WROOM-32 Bluetooth module consumes the second most power. While these three modules do consume the most power, they also come with a lot of features that will be useful for the Smart Hub Light System. The module that consumed the least amount of power surprisingly was the Cyble-022001 Bluetooth Module. The overall cost of this module however would increase by 71% if the team was to choose this module. Lastly, the RN4020 Bluetooth Module consumed the second least amount of power out of the five Bluetooth modules, however this module does include a sufficient amount of memory which will be needed for the Smart Hub Light System. So the last comparison for the Bluetooth modules will be the range of the Bluetooth modules.

3.7.1.5 Comparison of the Bluetooth Modules Versus Range

The last comparison of the Bluetooth modules will be the range that each of the five modules can work at. The reason why distance is important in terms of the Smart Hub Light System is because the team wants to ensure that there will be no data lost from the Bluetooth module. Looking at the table above, it can be seen that the RN4020 provides the most distance for the Bluetooth modules out of the five Bluetooth modules. In the other tables however, the RN4020 does not have the right amount of memory and would increase the system cost by over 100%. With the BC832 and BT832, they both have the same amount of distance however in terms of cost, the BT832 is cheaper than the BC832. The least amount of range out of the five Bluetooth modules is the Cyble-022001 Bluetooth Module. This module however if chosen, would only increase the system price by 70%. The last module which is the ESP-WROOM-32 module only has a range of 25 meters. While this is not bad and the cost for this is low, the module does not have any internal memory so it would make it difficult for the team to use the module. The next section will compare the five Wi-Fi modules before the team decides on whether they would like to proceed with Wi-Fi or Bluetooth implementation.

3.7.2 Comparison of the Wi-Fi Modules

From the section above on Wi-Fi modules, the team has narrowed down that list to just five Wi-Fi modules. The five Wi-Fi modules are ESP8266, XBee Wi-Fi module, Intel Edision and Mini Breakout kit, the EMW3162 Wi-Fi module and the ESP-07S Wi-Fi module. The reason as to why the TI SimpleLink CC3000 was eliminated was because the overall cost of this Wi-Fi module was too high. The ESP-01 Wi-Fi shield was eliminated because the team would still have to purchase the ESP-01 Wi-Fi card. This would mean that the team would be going over their budget because they would be purchasing two components instead of one. The reason why the Arduino Uno Wi-Fi Microcontroller was eliminated was because this is basically a microcontroller that already includes a built-in Wi-Fi card. While it would be easy to use that, the team feels that it would not cover the overall goals of the Smart Hub Light System. The reason why the ME Wi-Fi module was eliminated was because the team felt that this module would consume too much power for the Smart Hub Light System. The reason why the RTL8710 was eliminated was because this Wi-Fi module is limited to only one microcontroller and would not be able to perform the tasks that are required by the Smart Hub Light System. The reason why the TinyShield was eliminated was because the cost for this Wi-Fi module was too high. The five Wi-Fi modules will be compared to in terms of cost, power consumption, memory size, GPIO pins, and Package Size. The reason why the team is comparing package size is because they want the Smart Hub Light System to be small and compact.

3.7.2.1 Comparison of Wi-Fi Modules Versus Cost

The first comparison for the five Wi-Fi modules will be in terms of cost. As stated previously, the team does not want to spend a significant amount of money on the Wi-Fi module because it would deplete the teams' budget in other aspects of the design of the Smart Hub Light System. A table for the comparison can be found below.

Table 4 - Comparison of Wi-Fi Modules and Cost

Wi-Fi Modules	Unit Price	Power Consumption (mW)	Flash Memory	GPIO Pin Count
ESP8266 Wi-Fi Module	$6.95	0.033 mW	1 MB	16
Xbee Wi-Fi Module	$43.95	1019.7 mW	72 MB	10
Intel Edison And Mini Breakout Kit	$74.95	35 mW	4 GB	12
EMW3162 Wi-Fi Shield	$9.95	1760 mW	1 MB	14
ESP-07S Wi-Fi Transceiver Module	$4.66	720 mW	4 MB	0

After looking at the table above, it can be seen that the cheapest module out of the five Wi-Fi modules is the ESP-07S. Both the Intel Edison and the Xbee Wi-Fi modules are way too costly for the Smart Hub Light System. The system price increase for the Xbee Wi-Fi module is almost 1000%, while the system price increase for the implementation of the Intel Edison is over 1500%. The EMW3162 has a system price increase that is almost 130%. While this is not too bad for the team, the overall issue is that the team is not sure that this module will be able to handle goals of the Smart Hub Light System. The ESP8266 Wi-Fi module on the other hand would result in a 50% system price increase. While this is not bad, the team feels that it would like to consider the other comparisons.

3.7.2.2 Comparison of Wi-Fi modules versus Power Consumption

In this section, the five Wi-Fi modules will be compared to in terms of power consumption. The reason why this is important, again, is because the overall goal of designing a device or module is to ensure that the module or device consumes the least amount of power that is possible. After looking at the table above, it can be seen that the ESP8266 Wi-Fi consumes the least amount of power. In terms of the Xbee and the EMW3162 Wi-Fi modules, these modules consumes around one to two watts. That is a lot of power being taken into a Wi-Fi card and the team feels that because the power consumption of these two modules are so high, that it will affect the overall goal of having a low power consumption for the Smart Hub Light System. The ESP-07 module consumes 0.7 watts. While that is not too bad, the team still feels that this will affect the overall power being consumed by the Smart Hub Light System. In terms of the Intel Edison and Mini Breakout, this module consumes only 35 mW which is very reasonable in terms of the amount of power being consumed. The only negative part about using this module is that it would cost the team too much money. The next comparison will be based upon the amount of memory that comes with these Wi-Fi modules.

3.7.2.3 Comparison of the Wi-Fi modules Versus Memory Size

In this section, the comparison will be based upon the amount of memory that is included with each of the Wi-Fi modules. The reason as to why this is important, again, the more memory that comes with the Wi-Fi modules, the more faster the module will be able to process data going from the cellular device to the microcontroller. Another reason why this is important is because the team does not want to have a long delay time when the data transfer is occurring. Looking at the table above, it can be seen that the Intel Edison and Mini Breakout Kit offers the most memory out of the five Wi-Fi modules however, this module costs the most out of the five Wi-Fi modules. The Xbee module includes only flash memory and still costs a lot more than most of the Wi-Fi modules listed above. The ESP8266 includes 1MB of flash memory which is pretty decent but no RAM memory. However, the overall cost of the ESP8266 is reasonable. The EMW3162 includes both RAM and flash memory, but the issue is that it consumes the most power out of the five Wi-Fi modules. The ESP-07 Wi-Fi module includes only flash memory but this module costs the least amount. In the next section, the Wi-Fi modules will be compared to the amount of GPIO pins that are included in each of the Wi-Fi modules.

3.7.2.4 Comparison of the Wi-Fi modules Versus GPIO Pins

In this section, the five Wi-Fi modules will be compared to each other based upon the number of GPIO pins that come included on the Wi-Fi modules. The reason why this is important is because of the amount of ports that are going to be utilized for the Smart Hub Light System. In the table above, it can be seen that the ESP8266 includes the most GPIO pins and also consumes barely any power. The cost of the ESP8266 is also fairly reasonable. The ESP-07S Wi-Fi module has zero GPIO pins which will become a problem when the team is trying to connect the microcontroller to the cellular device. The Xbee and Intel Edison mini breakout Wi-Fi modules include roughly around the same amount of GPIO pins, the only issue is that the cost for these two modules are relatively high. The EMW3162 also has roughly the same amount of GPIO pins as the previous modules except that the overall cost for the ESP3162 is significantly smaller than the two previous modules. The final comparison for the Wi-Fi module will be the package size for the module.

3.7.2.5 Comparison of the Wi-Fi modules Versus Package Size

Why is package size so important? Well the reason why the team feels like the package size is so important is because the team is trying to develop a Smart Hub Light System that is relatively compact and small. The team wants the Smart Hub Light System to be as compact because the team want the device to be portable. In the table above, it can be seen that the EMW3162 is the Wi-Fi module that is the smallest out of the five Wi-Fi modules. The only issue with this module is that it consumes the most power out of the five Modules. The ESP8266 and the Xbee Wi-Fi module are roughly the same size but in the case of the Xbee module, the system price would increase by almost 1000%. With the ESP-07S Wi-Fi module, the overall size of this module is relatively small but the major drawback with this module is that there are no GPIO pins included with this Wi-Fi module. Lastly, with the Intel Edison and Mini Breakout Wi-Fi module, the overall size is large compared to the other four Wi-Fi modules. Not only that but the cost of this module is the most out of the five modules. In the next section, the team will decide between Bluetooth or Wi-Fi implementation and will select the module that will be implemented in the Smart Hub Light System.

3.7.3 Wireless Communication Choice: Wi-Fi

For the proposed Smart Light Hub system, Wi-Fi was selected as the primary form of wireless communication to be implemented. One of the main reasons for this choice is the short range of Bluetooth devices. The proposed system is primarily going to be used in a user's home, so if the user has a large house there is a risk of the Piconets disconnecting with the Bluetooth. Wi-Fi does not have this range issue, if the user has a good router or a Wi-Fi extender, range should not be a problem. The benefits which Bluetooth provides are also not really required for the proposed system. The system should not be streaming audio, so the BR/EDR would not benefit the system. Also, the system should have a continuous source of power so there would also not be a large benefit from the low energy Bluetooth. Wi-Fi also has high transfer speeds, since this system will have multiple components which are required to communicate this speed will be beneficial. Along with Wi-Fi our proposed system could implement the use of the ZigBee wireless language, if needed. ZigBee would enable the LED's in the proposed system to communicate with each other. Reducing the risk of a failed connection between and LED and the bridge.

3.7.4 Wi-Fi Module Choice: ESP8266

So after comparing the five Wi-Fi modules, the ESP8266 was selected as the primary Wi-Fi module that will be utilized in the Smart Hub Light System. The reason why this module was selected was because out of the five Wi-Fi modules that were compared, the ESP8266 was the better choice out of the five. The ESP8266 is relatively cost effective and will meet the goals of the Smart Hub Light System. The power consumed by this tiny module is relatively minuscule and will not affect the overall power that is being consumed by the Smart Hub Light System. The overall memory size that comes with this module is very reasonable for the cost of the module. The team feels that this module will exceed the overall specifications of the Smart Hub Light System. Comparing this module to the Intel module, the intel module by far costs way too much for the team and is too large for the design that the team is trying to achieve. The ESP07 is the cheaper than the ESP8266, but this module does not include any GPIO pins which is a huge drawback for the team. The EMW3162 consumed too much power compared to the other Wi-Fi modules and the cost of this Wi-Fi module would have increased the system price by 71%. The Xbee module did not include much compared to the other Wi-Fi modules and cost the second most out of the five Wi-Fi modules.

3.8 Mobile Platforms

To interact with the proposed system, we would like to use a device that everyone use in their everyday actives so users don’t have to purchase an additional device to use the system. Developing a mobile application that can give the user control over the system is the ideal case to capture the maximum amount of people will trying are system. To better understand how the different mobile platforms will affect the development of the product in question the team will discuss the different platforms and do an analysis on the smart phone market and provide closing remarks on the platform of their chose.

3.8.1 IOS

The native integrated development environment for developing iPhone mobile applications is the Xcode. To write programs in Xcode swift and Objective-C are the native supported languages. Apple introduced swift to move away from objective to decrease the time developers spend working on the mobile to application to increase the turnaround time. Swift offers a lot of libraries to supports development of applications developers are working on. A drawback with working with Xcode is that a developer need to have apple laptop which could be a big beginning investment for an individual to make.

When it comes to hardware the iPhone has a limit number of devices you can develop for. That being said when developing an application, you need to find out what is the expect hardware limitation of the application that will be running on the device. So, the developer can cut support off at the appropriate iPhone generation. Also, operating systems being able using to by user can impact the development life cycle. A benefit of this is that that apple can push new features without having to worry about the impact to all the generation all IOS in the market. In Figure 7 we can see how the distribution of IOS version used on March 16, 2017 the market is fragment by version but it does not go far back. This make it easy to build an application that can grab a larger majority of the market with having to stress how the implementation will impact the entire market.

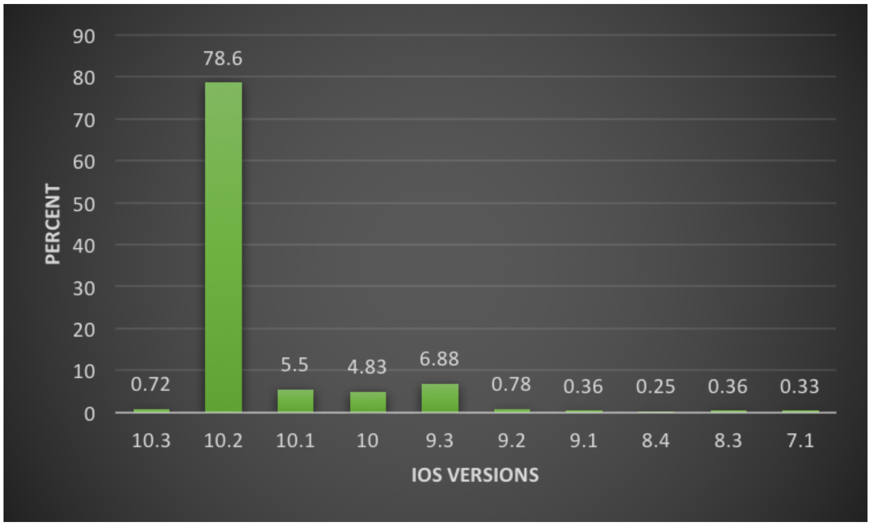


Figure 7 - IOS Distribution

Another question in developing a IPhone mobile application is how the publishing process impacts the ability to make it to the store. To deploy an application to apples app store the following thing to be done or passed in order to make it the store other. Some of these checks might pose to be problematic for a first-time or veteran developer publishing to the apple app store. to gain the ability to publish to the app store you need to have a developer account with apple, which includes a $99 annual fee. This fee is used to offset the cost of testing your app. Apple inspects all source code using a human to make sure that what is being submitted is not malicious. This process takes a few days and its possible for your to just plan rejected because of an obscure reason as it has happened in the pass.

3.8.2 Android

The native integrated development environment for the developing android mobile applications is android studios. To write programs in android studios the developer the option of using the NDK which allows you to write the application in its native language C or C++. However, google has also implemented the android software development kit which makes it easy to get up to speed with programming a mobile application opposed to working with C/C++. The SDK let you write you application in java so developers don't have to worry about pointers and figuring out when is it best to free memory. this also provides a layer of security so eliminate memory leaks. This lens its self to a decrease development time. Also, java has a massive number of supported libraries to help speed the development. A downfall of the android studios would have to be its bulkiness as it consumes a considerable amount of your systems resources to get it working.

The number of different android device allow for a variety of different hardware specification that can be taken advantage of when developing for android. This has its benefits and downfall. As the developer, you need to find the device market that you would like to target but you would also have to find the operating systems you would like to provide support making it hard to pick the cutoff point. Figure 8 shows the market manufacture distribution for android devices. The most popular manufacture for data gathered on March 16, 2017 shows the current android market favors Samsung manufactured devices.

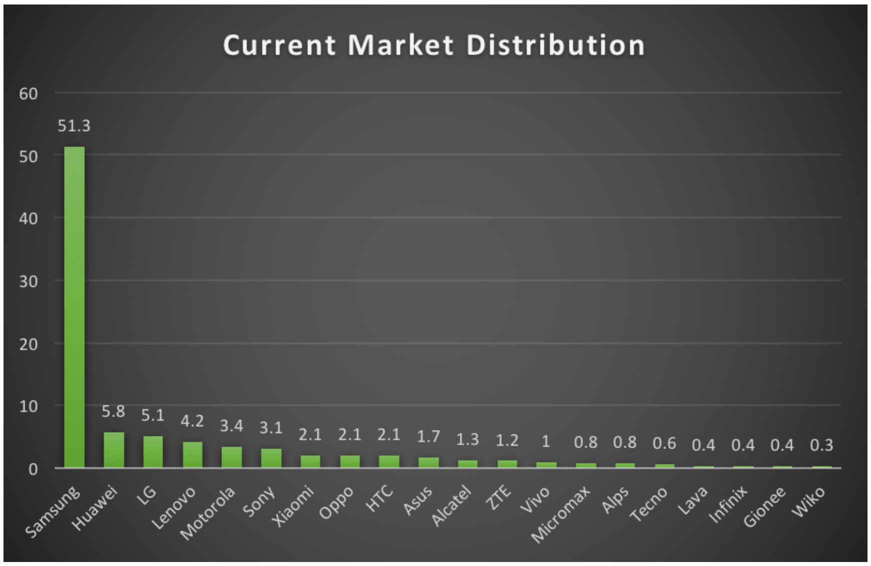


Figure 8 - Android Market Distribution

Since the android market is broken in to different hardware platforms. As developer, you might want to consider the different operating system that are available to program. you would need to get a better understanding how the market is shifted so that you can develop your application with the necessary support. So, you can target the general population of devices being used by people. Android OS market distribution can be showed in Figure 9. At a first glance one can see that you SDK version 5.0 – 5.1 lollipop is the most popular version in the current market and the newer version marshmallow is about as popular so if you were to pick a support point based on the information gather on March 16, 2017 a developer might decide to choose 4.4 KitKat as the support cutoff point.

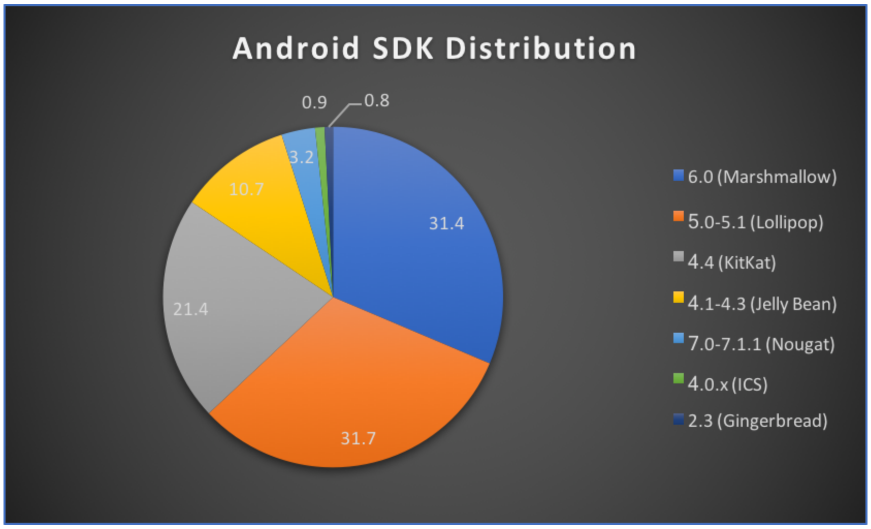


Figure 9 - Android SDK Distribution

Lastly, when publishing an application to the google play store a developer must follow and passes these requirements in order to successfully make it to the google paly store. To publish your application, you need to make a onetime payment of $25. Typically, your application is published to the google play store within a few hours of it being summited. A benefit that android development provides is the ability to deploy to the market swiftly. However, there is an underlining drawback to this which can cause a problem for the android market. By not putting applications under a strenuous test before deploying it to the store they allow for many possibilities of viruses to affect their market.

3.8.3 Market Differences

To further understand the difference in the mobile application market let's take a look into the how the market is split between different platforms. Understanding the split in the market can give developers a decision factor for developing for a particular platform. Looking at Figure 10 we can see the market is split between two big company's while others are such a small fraction of the total we can ignore those makers. Android holds 86.2 percent of the total market; this number makes sense because the android make target all types of people of different financial back grounds. So, a user can get a smart device that is in their price range. The second company that hold a larger proportion of the maker is apple with 12.9 percent of market they target two major area of the market that being. They make a smart phone that is more on the luxury side of smart phones being more expensive than their competition. However, with them doing that they don't sacrifice the quality of their phone. That is the main reason they are able to hold a large proportion of the market without having many devices that support their OS.

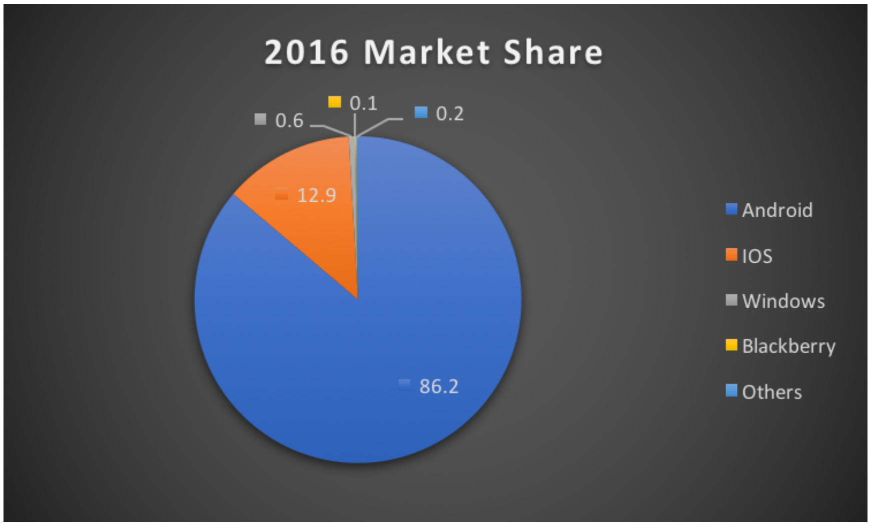


Figure 10 - Smart Phone Market Share

3.9 Development Environment

The proposed system will consist of a mobile application, this mobile application will require an Integrated Development Environment (IDE), to be developed. We will take a tool at different IDE to shows the benefit and drawback. To choose a IDE that will fit are overall intended needs. We will focus on two IDE Android Studios and Visual Studios.

3.9.1 Android Studio

The official IDE for Android application development is Android Studio. This IDE is based off the IntelliJ IDE, the IntelliJ IDEA. Android studio is the Android app development IDE of choice since it offers features which enhance productivity for Android development. Along with access to a developer tools, and a robust code editor, Android Studio ha build in GitHub Integration. GitHub is service which enables version control. Version control is a powerful tool when developing an application with a team. Android Studio has built in emulators of a plethora of Android devices which makes testing simple and efficient. Android Studio also has a powerful Graphical User Interface for developing the user interface of an application. This tool will expedite this portion of the development process since, the interface can be developed for the correct device. [14]

3.9.2 Visual Studios

Visual studies in an integrated development environment made by Microsoft. This IDE allows for cross platform development for IOS and Android this can be very useful when trying to enter two different smart phone market as it provides quick turnaround time for development. However, the developer has to be familiar with C# to so. Visual studios its able to do this because Microsoft own a company called Xamarin. The developers at

Xamarin have focused on developing tools to provide cross platform development. Like Android studios, visual studios provide the same feature such as built in version control, GUI tools and testing tools. However, there is a one downfall to developing an application of a cross platform tools that being that it is possible to have a performance drop off because development is not being done with the device native languages.

3.9.3 Arduino IDE

Being an open-source prototyping platform for electronics Arduino is provides simple to use hardware, as well as software. [15] The Arduino microcontroller is the primary microcontroller for the proposed system. As a result, the Arduino Integrated development environment was selected to program this microcontroller. The Arduino IDE is an open-source environment written in Java, which allows users to upload their code onto the board. This environment allows users to program in C/C++, user can easily access all the ports on the board allowing full control of what the board does. [16]

3.9.4 Visual Studio Code

Along with the IDE's code can be written in text editors, when the additional capabilities of an IDE aren't required. The proposed system will also require node.js, a JavaScript framework, for some of the serverless communications using google cloud functions. The programming for this portion of the system would not need any of the capabilities offered by the IDE's. Visual Studio Code is a new text editor which is very powerful and lightweight. This editor comes with built in support for many language, node.js being one of them. Although it does not have all the capabilities of an IDE, Visual Studio Code combines some of those capabilities with the light weight simplicity a text editor. Some tools offered are code completion using IntelliSense, debugging and version control integration with GitHub.

3.9.5 IDE Selection

The proposed system will use be an Android based application. Android Studio is the preferred IDE. A few reasons for choosing Android studios over visual studios was the fact that the application can be built in JAVA a language the development team is familiar with. Since we are not trying to target IOS users we don't need a IDE that has cross platform capability's. another reason for not choosing visual studios in the cost associated to use the IDE. To develop an application on IOS and port it to the device for testing you must have a developer account with apple which is a cost that the teams does not what paid because we have a limited budget. However, to port an application to an android device come with no associated cost to do so.

The secondary IDE selected will be the Arduino IDE, this will be used to program the Arduino microcontroller for the proposed system. This Environment was selected since it is one of the best IDE's for the Arduino, and allows use of the C programming language to program the Arduino board. This IDE will greatly simplify the programming of the board since it allows full control of the board.

Visual Studio Code will be used as the third development environment. This will provide a light weight editor for writing node.js. This was selected since it is currently one of the best text editors out. It is very powerful and has many developer tools at its disposal, especially the built in support for node.js development.

3.9.6 Eagle CAD

One of the development software that will be utilized in the development of the Smart Hub Light System is Eagle CAD. Eagle CAD is a software application that is used to design different schematics for different projects that any consumer wants to develop. Eagle CAD will come in handy with the development of the final schematic for the Smart Hub Light System. Eagle CAD is available for free for students and others that need a schematic diagram for their projects and circuit designs. Eagle CAD is basically a PCB layout software that includes multiple schematics of components. There are multiple things that a consumer can do with Eagle CAD. From developing schematic diagrams to running real time design synchronization, Eagle CAD is one of the most used PCB design software around the world. Eagle CAD is available for free for all consumers and it also has a subscription option that includes 999 schematic sheets, 16 signal layers, and unlimited board access. Access to this option of Eagle CAD is called the premium version of Eagle CAD and is costs around $65 for a monthly subscription, $500 for a one year subscription, $1000 for a two year subscription and $1500 for a three year subscription. There is another subscriber option called the EAGLE Standard option. This option includes 99 schematic sheets, 4 signal layers, and a 160-centimeter squared board area. The cost for this subscriber option is $15 per month, $100 per year, $200 for a two year subscription and $300 for a three year subscription. The free version of Eagle CAD includes two schematic sheets, two signal layers, and an 80-centimenter squared board area. So in the teams' best interest, we selected to use the free option of Eagle CAD to develop the final schematic for the Smart Hub Light System. Another good feature with Eagle CAD is that it is available to be used on Windows Computers, Macintosh computers and Linux based computers. All in all, this software is very useful not only to the team but to Electrical Engineers all over the world that are designing and building different components for their careers.

3.10 Database

The proposed system will use an Android based mobile application. This application will support multiple users as well as the customizable lighting preferences for a user. This data must be stored, such that a user can log into an application and view, edit or delete their preferences. To store this data a database will need to be implemented. Android studio has a few databases which can be easily used in conjuncture. A couple of these are Firebase and SQLite.

3.10.1 Firebase

Firebase is a NoSQL cloud hosted Real-time Database owned by Google. JavaScript Object Notation (JSON) is used to store the data in a Firebase Database. Data in a Firebase database is also updated in real-time for all users connected. Firebase allows users to share one real-time database, instance across multiple platforms, such as iOS, Android and JavaScript. Firebase data also remains even when the application is not online.

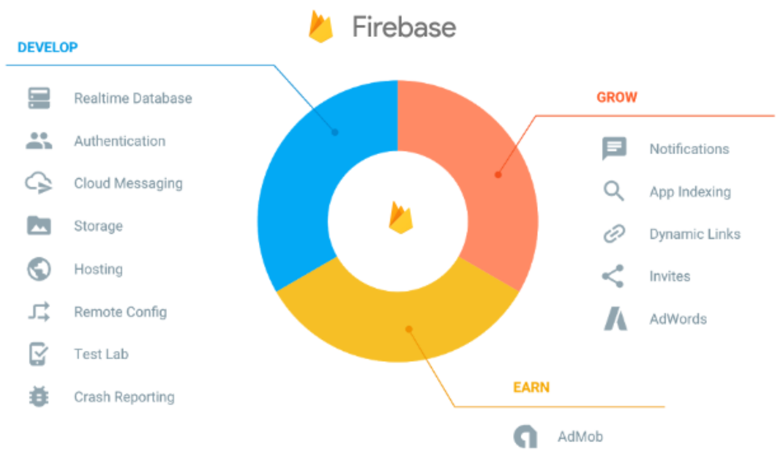


Figure 11 – Firebase

From Client-side code secure access to the Firebase database is granted. This data is available even when the application is offline since it is persisted locally. Although to give the end user a responsive experience real-time events continue to execute. The updates that took place while the application was offline are not lost, once the application re-enables its online connection the real-time database synchronizes the changes and resolves any conflict with the data. Firebase provides a scalable real-time experience, and allows quickly executing operations thanks to the design of the Real-time Database API.

Firebase has many capabilities and benefits the most notable being the data synchronization because of the Real-time Database. The responsiveness of the applications even when they are offline. As well as the firebase database being accessible from any web browser or mobile device. [17] Firebase also offers notifications, cloud messaging, crash reporting and more. [18]

3.10.2 SQLite

Originating in 2000 being an embedded SQL database engine, SQLite is server less, transactional, self- contained and requires zero-configuration. A separated server

process is not required with SQLite since it is a server less database. Ordinary disk are used for reading and writing in an SQLite database. An SQLite database can be used cross-platform, and the entire database can be stored on a single disk file. This flexibility makes SQLite popular for application development. The size of an SQLite database is very minimal, and can be less than about 500KB, which is optimal for targeting mobile devices. [19]
A benefit which make SQLite easy to implement into a mobile application is that it is a Zero-Configuration Database. SQLite does not need to be installed or setup before it is used. The system will know SQLite is running without any work needing to be completed. [20]

SQLite being server less is another benefit for mobile development. This server less capability is linked to the zero configuration, as there is no installation, or setup process. Since there is no server administrative support is also not required. With this server less implementation any program that has read/write access to the disk can use SQLite. There are some downsides to this server less implementation, such as the database no longer has the protection that a server based database would. [21]

3.10.3 Database Selection

The proposed system will implement the use of a Firebase Database. This database was chosen simply because of its many benefits. Such as being a cloud hosted real-time database and is continuously synced with each client so all data is constantly up to date. Firebase also removes the need to create your own database and provides rules based on expressions which can define how data will be organized.
Authentication through Firebase is made simple, and allows users to create with Email Addresses, passwords, usernames, or even Facebook and Google logins. The proposed system will support multiple users, thus there must be some form of authentication in place to allow each user to log in to the application and view the content related to them. These users should be allowed to store information such as, how many LED’s they have connected, their preset lighting settings, personal account information and the states of their LED’s, since firebase is a real-time database that information will be updated and it will not be lost once they close or reenter the application.
Firebase helps with finding and managing errors by providing crash reports. When an error occurs, a detailed report will be created, also the steps which lead to the crash can be recorded as well. Test lab also allows testing of the application before the code is completed, which enables errors to be found, before development is completed. [22]

3.11 LED & Light Bulbs

The Smart Light Hub will use either an LED light strip or multi colored light bulbs to illuminate the area which the user wants. The important aspect about the lights are that they are efficient and easy to use. This section will go on to discuss about the different

LED light strips and different light bulbs which are currently in the market today and go into detail about which one would be best suited for the project.

3.11.1 Miniature LED

With the advancement in technology it has allowed for smaller LEDs, better illumination, lower power consumption and longer service life. The most common form of LED is perhaps the miniature LEDs which are meniscal compared to normal LED lights. These LEDs are mostly used as indicators for devices such as the remote control for your TV, The indicators for cellphones such as the Galaxy S7 edge, and for Calculators such as the TI-Nspire. The benefits of the small form factor is that it can be easily used without the need for heat-controlling or cooling devices and can be installed directly onto the breadboard. There are three different types of miniature LEDs: low-current, standard, and ultra-high-output. The difference between these three LEDs is that they vary in current, voltage and wattage depending on the manufacturer. Miniature LEDs are also available in 5-12V. The difference between these LEDs from the normal miniature LEDs is that they incorporate a series of resistors which allows it to be directly connected to a higher power supply.

An example of a Miniature LED is SMD(Surface Mounted Device). These are extremely small and are mainly intended for industrial applications. Because of its small size it only allow soldering by machines. One type of SMD is the Nichia NF2L757DR 108lm warm white. It uses between .6 to 1 W and can be used either alone or connected with other LEDs.

Figure 12 -Nichia NF2L757DR 108lm

3.11.2 High-Power LEDs

The next type of LEDs is the High-power LEDs. With the recent innovation in LEDs it has resulted in a new type of LED which are called the high-output LED and the difference between this LED and miniature LED is it has a higher lumen output which is the amount of light which is being omitted. The high-power LEDs are so powerful that it can emit several thousand lumens. When it comes to designing anything with high-power LEDs it must be mounted on a heat-absorbent material or fan to keep the LED cool since it generates so much heat which could pose a danger to overheating. The heat-absorbent material will cool the LED by convection which keeps the product from an early burn-out. Some examples of high-power LEDs are in high-power lamps, car headlights, and various industrial, scientific and mechanical settings.

An example of a High-Power LED is the 120 Watt High Powered Recessed LED Light 100-240VAC. This light is great for places such as a warehouse or for industrial use. It has a lumen output of 13,200. It's made of aluminum and PC.

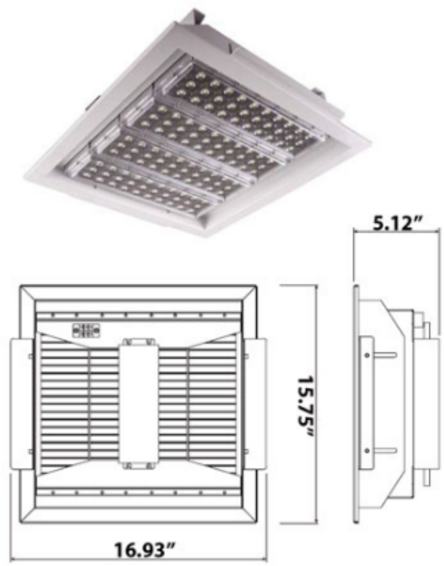


Figure 13 - 120 Watt High Powered Recessed LED Light 100-240VAC

3.11.3 Application-specific LED lights

The first type of application specific LED is the flashing LED. This kind of LED is most common and serves as a form of attention-seeking indication. The sign might look like a normal LED but it contains an integrated circuit. The lights are meant to flash at a specific frequency and can be connected directly to a power supply without the use of series resistors. Some examples of Flashing LEDs are in vehicles and signs.

The second type of application-specific LED are the Bi-color and Tri-color LEDs. In a bi-color LED the light has two light-emitting dies in a casing. The bi-color LED is wired in "inverse parallel", this means one is forward and the other is backward. When an LED is wired in inverse parallel it makes it so only one LED can be on at a time when given power. For the LED to produce different colors the current flow alternates between the dies. If the current is altered at a high enough frequency, it will appear as if both lights are on at the same time which will produce a third color.

In a tri-color LED the two light emitting dies are also in one encasing just like the bi-color LED. The difference between the tri-color LED and bi-color LED is that the tri-color LED has three leads instead. The two leads on each side of the LED are the outer leads, these are the anodes to the separate LEDs. The center lead is the common cathode for both LEDs. With this type of design, it allows for the dies to be lit either separately or together. When these colors are combined, it procures a third color. Tri-color LEDs are available in either a common cathode or common anode configuration.

The next kind of LEDs are the red, green, blue (RGB) LEDs. The RBG LEDs include red, green and blue emitters, which when combined can produce millions of different colors. Most RBG LEDs use a 4-pin connection with a common lead. Since the light need electronic circuits to control the combination and diffusion of different controls, RBG LEDs have high level of accuracy when it comes to control of color emission. RBG has become a new popular LED since it has a wide variety of applications. They are common in video display, accent lighting, indicators, light shows, and even in computer keyboard and mouse.

The next type of LED is the alphanumeric LED light. This kind of LED has fallen in popularity in recent years since advancement in sophistication of LCDs, which offer greater visual representation and use much less power consumption. There are different types of alphanumeric LEDs from 7 segment, 14 segment, 16 segment, and 5 x 7 matrix. The 7 segment handles all single digit number and a few letters. The 14 and 16 segment displays cover the 26-character roman alphabet and numbers from 0-9. For the matrix, it covers the full alphabet and variety of symbols.

The last type of application-specific LED lights are the lighting LEDs. Lighting LEDs are also called LED lamps, LED bars, or illuminators. Lighting LEDs come in many different size and shapes including the normal light bulbs used in homes. These kinds of LEDs produce high amounts of heat so engineers have designed light bulbs to have aluminum or ceramic body since those types of metal are good with dissipating heat. Some bulbs even come with fins to increase the total surface area to help heat escape.

3.12 Display Implementations

This Section discusses the different display setups and the pros and cons of each one.

3.12.1 SPI Controlled LED lights

Looking into the options for the Smart Hub Light System’s LEDs, the team investigated the SPI controlled LED lights. To start off, SPI stands for serial peripheral interface bus. It’s a synchronous serial communication interface specification used for short distance communication. SPI devices can communicate with each other in full duplex mode using a master to slave architecture with a single master. The master device originates the frame for reading and writing. Multiple slave devices are supported through selection with individual slave select lines. The SPI bus specifies logic signals. The first logic signal is the SCLK. This stands for Serial Clock and represents the output from the master. The second logic signal is the MOSI signal. This stands for Master Output Slave Input and represents the data output from the master. The next logic signal is the MISO signal. MISO stands for Master Input Slave Output and represents the data output from the Slave. The next logic signal is the SDIO signal. This signal stands for Serial Data Input/Output. This logic signal is bidirectional meaning it can act both as an input or as an output. The last logic signal is the SS signal and it stands for Slave Select and represents an active low output from the master. A figure depicting the SPI interface can be found below.

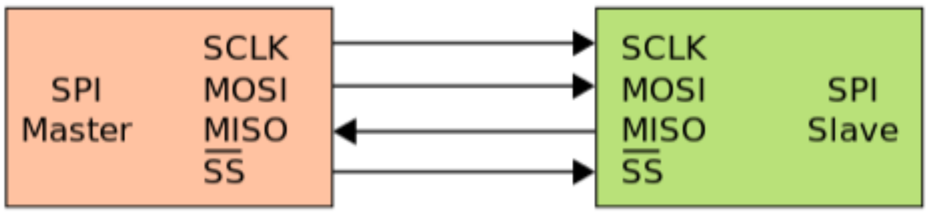


Figure 14 - SPI Block Diagram

The wat that SPI LEDs work is basically the user sends a message to the LEDs and the LEDs will then respond by either producing a pattern or simply turning on the LED. Once the message has been delivered, the software will move on to the next message and repeat the same process over again. Overall, while SPI LED Lights is an option for the team, there is also a drawback with using SPI. Because SPI transmits the data one bit at a time, the response time for the overall device will be significantly. Because of this, the team feels that there are a lot more options for the type of LEDs that will be implemented in the Smart Hub Light System. In the next section, the team will discuss I2C Enabled LED lights.

3.12.2 I2C Enabled LED lights

The next type of LED display that will be discussed is the I2C Enabled LED Lights. I2C is another serial communication bus that is similar to the SPI serial communication bus. I2C stands for Inter-Integrated Circuit and is a multi-master, multi-slave, packet switched, single-ended serial computer bus that was invented by Philips Semiconductor. This interface is typically used for lower-speed peripheral integrated chips to processors and microcontrollers that are in a short, intra-board communication.

One I2C enabled LED that is being considered for the Smart Hub Light system is the Blink-M LED. BlinkM is a “Smart LED”, a networkable and programmable full-color RGB LED for hobbyists, industrial designers, prototypers, and experimenters. It is designed to allow the easy addition of dynamic indicators, displays, and lighting to existing or new projects. One feature for the BlinkM LED is that it comes with 8000mcd 140º full-color RGB LED with 24-bit color control and can specify colors by 24-bit RGB or HSB. It is also capable of fading between colors with variable timing and fade speeds and also comes with a randomized color selection, with ranges and based on previous color. This LED can be combined with up to 127 BlinkM LEDs on a single I2C network. This module is capable of handling a voltage input of 5 Volts and has a low power consumption. A figure displaying the BlinkM LED can be found below.

Figure 15 - BLinkM I2C LED

After comparing the two previous communications, the team felt that there are still more LED displays that the team can compare to. In the next section, the team is going to discuss the WS2811/WS2812 LED Lights.

3.12.3 WS2811/WS2812 LED lights

The WS2811/WS2812 RGB LED driver boards are the best LED drivers for the Smart Light Hub since it has many features which are needed for the project while also having a relatively low cost. Also the LEDs have a simple control system which will save time and allow for more time to be used for other parts of the project. WS2812 devices require a singular input line of data and repeat once the register is filled. The advantage of this is that it allows for an almost unlimited number of LEDs in a serial control line. The only issue of using a system that sends a singular input is that it causes a delay since it has to go through all the LEDs before a new instruction is made. This means the big issue is the refresh rate of the LEDs and the amount of power which the LEDs draw. For The Smart Light Hub there will be 3 rows of LEDs which will eliminate the power issues since each row of LEDs can have their own power source. With the refresh rate that the WS2811/WS2812 has it means that their needs to be a large amount of data generation and a certain type of control signal. Even though it WS2811/WS2812 has these constraints the ease of operation and cost of the LEDs make this a great choice for the Smart Light Hub.

3.12 Printed Circuit Board

A printed circuit board (PCB) is a way to electrically connect electronic components using conductive tracks and pads which are made from copper sheets laminated onto a nonconductive substrate. PCB are the most common way for engineers to assemble modern electronic circuits. Components such as capacitors, resistors or active devise are generally soldered on the PCB. There are several types of PCBs, one kind is a single sided which has one copper layer, double sided which have two copper layers, and a multi-layer PCB. Most of the modern systems use multilayer boards with over 7 layers. Before components used to be added on the top layer in holes of the PCB through the layers. Recently PCBs have changed from hold components to surface mounted components. The benefit of this is that components can be mounted on both top and bottom layers. This allows for more components to be added while making the size of the PCB smaller. PCBs are popular since they dramatically improve the durability and are smaller than using a breadboard of electronic products.

3.12.1 Composition of a PCB

PCBs are like a layer of cake in that there are alternating layers of varied materials which are laminated together with heat and adhesive to make a PCB.

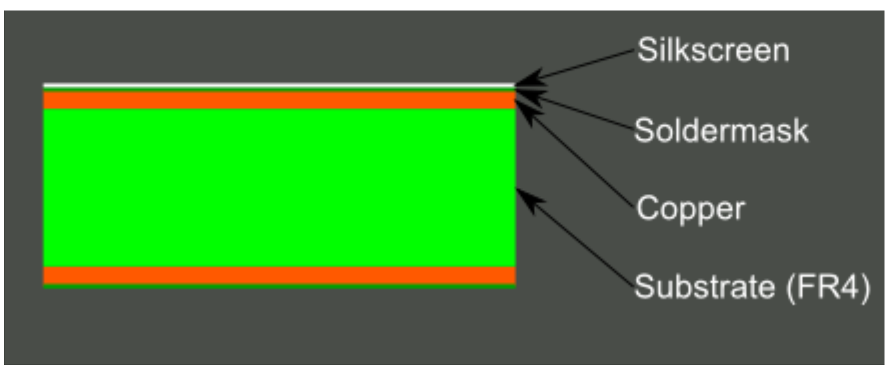


Figure 16 - PCB Composition

Substrate(FR4) [23]

The substrate which is also the base material for the PCB is usually comprised of fiberglass. The most common type of fiberglass is the FR4. The purpose of the substrate is to give the PCB a solid core which gives it rigidity and thickness allowing for the PCB to not break as easily. FR4 is a composite material which is woven fiberglass cloth with an epoxy resin blinder that is flame resistant. FR stands for flame retardant and is compliance with the standard UL94V-0. FR4 is a popular and versatile high-pressure thermoset plastic laminate grade with good strength to weight ratios. The great part is that there is zero water absorption which makes it so the components don't get short circuited. The material is also known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. With these attributes, it's a great use for a wide variety of electrical and mechanical applications.

Copper [24]

For the next layer in the PCB it's made from copper. This thin copper foil which is laminated to the board with heat and adhesive. The most common type of PCBs has double sided copper which means that copper is added to both sided of the substrate. For PCBs which are in lower end gadgets they may only have copper on one side. The number of layers of copper can vary from as few as 1 layer to as much as 16 and even more. When it comes to how much copper to add to a PCB it varies from manufacture but the vast majority of PCBs have around 1 ounce of copper per square foot. For PCBs which need to handle very high power they may have 2 to 3 ounces of copper per square foot. For measurement, each ounce per square is around 35 micrometers or about 1.4 thousandths of an inch of thickness of copper.

Soldermask [25]

The next layer in the PCB which is right above the copper foil is the soldermask layer. This layer is a thin lacquer like layer of polymer which is applied to the copper traces. This layer is the reason why the PCB has this green color too it. The reason of having a soldermask is to insulate the copper traces from accidental contact with other metal, solder, or conductive bits. This also makes it easier for the engineer to solder to the correct places and prevent solder jumpers. A solder jumper is an unintended electrical connection between two conductors by means of a small blob of solder. While it is important for hand soldered assemblies it is very essential for mass produced boards that are soldered automatically using reflow or solder bath techniques. Soldermask comes in different material depending on the demands of the application. The lowest costing solder mask is epoxy liquid that is silkscreened through the pattern onto the PCB. Another type is in liquid photoimageable solder mask inks and dry film photoimageable solder mask. These solder mask go through a thermal cure of some type after the patter is added to the copper.

Silkscreen

The surface layer of the PCB is the silkscreen layer. This white layer is applied on the top of the soldermask layer. The silkscreen adds letters, numbers, and symbols to the PCB which allows for easier assembly and indicators for humans to better understand the board. The silkscreen labels indicate what the function of each pin or LED. Silkscreen is most commonly white but can be any color.

PCB Terminology

Annular ring- The ring of copper around a plated through hole in a PCB.

DRC- design rule check. A software check of your design to make sure the design does not contain errors such as traces that incorrectly touch, traces too skinny, or drill holes that are too small.

Drill hit - places on a design where a hole should be drilled, or where they actually were drilled on the board. Inaccurate drill hits caused by dull bits are a common manufacturing issue.

Finger - exposed metal pads along the edge of a board, used to create a connection between two circuit boards. Common examples are along the edges of computer expansion or memory boards and older cartridge-based video games.

Mouse bites - an alternative to v-score for separating boards from panels. A number of drill hits are clustered close together, creating a weak spot where the board can be broken easily after the fact.

Pad - a portion of exposed metal on the surface of a board to which a component is soldered.

Panel - a larger circuit board composed of many smaller boards which will be broken apart before use. Automated circuit board handling equipment frequently has trouble with smaller boards, and by aggregating several boards together at once, they process can be sped up significantly.

Paste stencil - a thin, metal (or sometimes plastic) stencil which lies over the board, allowing solder paste to be deposited in specific areas during assembly.

Pick-and-place - the machine or process by which components are placed on a circuit board.

Plane - a continuous block of copper on a circuit board, define by borders rather than by a path. Also commonly called a “pour”.

Plated through hole - a hole on a board which has an annular ring and which is plated all the way through the board. May be a connection point for a through hole component, a via to pass a signal through, or a mounting hole.

Pogo pin - spring-loaded contact used to make a temporary connection for test or programming purposes.

Reflow - melting the solder to create joints between pads and component leads.

Slot - any hole in a board which is not round. Slots may or may not be plated. Slots sometimes add to add cost to the board because they require extra cut-out time.

Solder paste - small balls of solder suspended in a gel medium which, with the aid of a paste stencil, are applied to the surface mount pads on a PCB before the components are placed. During reflow, the solder in the paste melts, creating electrical and mechanical joints between the pads and the component.

Solder pot - a pot used to quickly hand solder boards with through hole components. Usually contains a small amount of molten solder into which the board is quickly dipped, leaving solder joints on all exposed pads.

Solder jumper - a small, unwanted blob of solder connecting two adjacent pins on a component on a circuit board.

Surface mount - construction method which allows components to be simply set on a board, not requiring that leads pass through holes in the board. This is the dominant method of assembly in use today, and allows boards to be populated quickly and easily.

Thermal - a small trace used to connect a pad to a plane. If a pad is not thermally relieved, it becomes difficult to get the pad to a high enough temperature to create a good solder joint. An improperly thermally relieved pad will feel “sticky” when you attempt to solder to it, and will take an abnormally long time to reflow.

Thieving - hatching, gridlines, or dots of copper left in areas of a board where no plane or traces exist. Reduces difficulty of etching because less time in the bath is required to remove unneeded copper.

Trace - a continuous path of copper on a circuit board.

V-score- a partial cut through a board, allowing the board to be easily snapped along a line.

Via - a hole in a board used to pass a signal from one layer to another. *Tented* vias are covered by soldermask to protect them from being soldered to. Vias where connectors and components are to be attached are often untented (uncovered) so that they can be easily soldered.

Wave solder - a method of soldering used on boards with through-hole components where the board is passed over a standing wave of molten solder, which adheres to exposed pads and component leads.

3.13 WIFI Communication

In this section, the different methods of communicating over Wi-Fi are discussed and the selected method of communicating over Wi-Fi is chosen. Since we will be communicating over Wi-Fi its vital that we choose a form of communication that can get data from one system to the other having constant connectivity, it's vital for our system. Since our system is completely wireless apart from the power, wireless communication is the core part of the project.

3.13.1 Access point

Using an access point to connect to the subsystem of the smart light hub. Where each component acts as a node to the network and your home router is acting as a middle man to the commutation with the device might be the ideal, it sounds like the ideal solution for the project however there is few things that need to be considered. If the system is connected to the internet it easily susceptible to being hacked with malicious intent. Giving the hacker the ability to control your lights in your home. This method does not provide the user with the best security option. Also, it's possible for this method to slow down some home network it might be supper noticeable but with are design we're trying to completely avoid this scenario.

3.13.2 Direct

With Wi-Fi, direct is possible to connect device without the need of an internet connection. this is good for internet of things applications with this functionality you can isolate your smart device from the internet and not have to worry about being potentially hacked by someone with malicious intents. We also do not have to worry about the bogging down the user home network. This method is extremely Beneficial for the smart light hub because we can take advantage of the long range of Wi-Fi and have security for our users. Another reason this type of Wi-Fi communication is ideal for are project is the fact that its implementation in all major smart phones operating system which makes it quick to write programs for. Developers can send more time making complex system rather than trying to setup drivers and build the system from starch.

3.13.3 WIFI Communication selection

For the smart light hub, we have chosen to use the Wi-Fi direct method because of the following reasons. The ability to provide are user with security by isolating the connection to the devices interfacing each other and still have the ability to take advantage of Wi-Fi's long distance. The group can design a system that is well rounded so it makes the users feel safe. The large support from large manufactures who design the major mobile operating systems. Providing the developer with a means to produce complex system in a short amount of time. These features that are provided by Wi-Fi direct is the perfect fit for our Smart Light Hub system.

3.14 Functions as a Service(FaaS)

In addition to the technology listed above, there are other technologies which will be used to supplement our application. Serverless computing is a new popular form of performing computations for developer's applications or systems. The "serverless" does not mean there are no servers, it is called serverless since the developers never have to worry about the servers, no management, or even scaling them. [27] Functions as a service allows computing services like Amazon Web Services(AWS) Lambda by Amazon or Googles Cloud Functions, to be hosted in the cloud and only respond when certain events happen. This enables applications to be lighter since the heavy computations do not need to be done inside the application but can be done in the cloud. These functions can handle any amount of request as they are built on top of serverless technology so they scale dynamically.

3.14.1 Amazon AWS Lambda

One of the major companies which offer Serverless computing solutions is Amazon, with AWS Lambda. Lambda allows developers to run code without having to manage the servers. Unlike with servers there is no cost associated if your code is not running. Code can be automatically triggered from the developer's application, website or AWS services. Lambda scales according to how many triggers the code receives which makes it perfect for a growing application. [28] HTTP request using Amazon API Gateway, changes in an Amazon S3 bucket or DynamoDB table can invoke Lambda code to run and execute the predetermined operation. [29]

AWS Lambda is useful when the developer can write the code for their application supported by Lambda, such as Node.js, and can write it to run in the Lambda runtime environment. Using Lambda allows user to only have to manage their code, and not the computation which AWS handles.

3.14.2 Google Cloud Functions

Google Cloud Functions allows developers to develop single purpose stand-alone functions. These functions respond cloud events and offer compute solutions which are light weight. A runtime environment or the management of a server are not necessary for this compute solution. [30]

Cloud functions allows creation and deployment of services in the form of units as small as a single function, so there is no need to deploy these services at the level of Virtual machines, containers or even applications. [31] This sometimes goes by the term Cloud Computing, and can execute logic in response to events from anywhere, this logic is a part of a fully serverless model of computing. These models can scale in size and don't require any management of infrastructure. Thus, if the proposed application grows in the number of users, there will be no need to adjust the infrastructure since the model is serverless. [31]

With Cloud Functions access to Google Cloud events and Firebase is given, allowing Firebase apps like the proposed systems Android application to use Cloud Functions to meet its use case. Some of the typical use cases are Notifying a user when something happens, such as if an app allows user to obtain followers, cloud function can be used to notify that user. The way this would work is on writes to the location where the followers are stored in a Real-time Database, the function would trigger and send a message, in the form of a Firebase Cloud Messaging message. This message would appear on the user's device, as shown in Figure 17. [32]

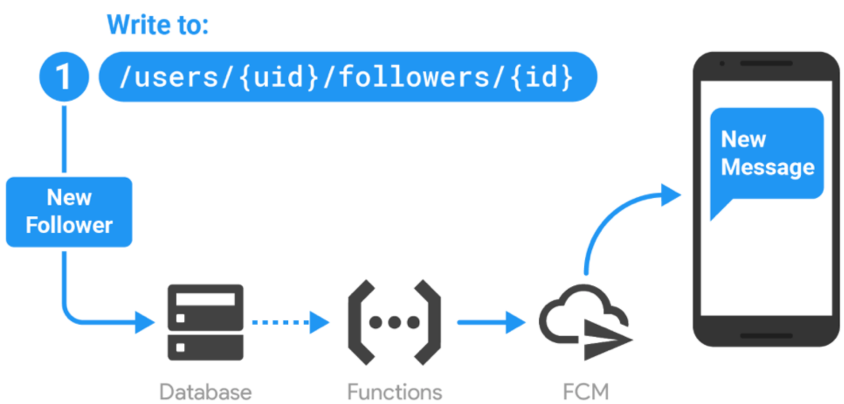


Figure 17 - Cloud Functions user notifications

For the proposed system, this type of function interaction with the user could come in useful. For example, when the user adds a new preset light setting, or changes the states of their lights, a notification could appear notifying the user of the update in the database. Another useful use case for Cloud functions would be executing vigorous task in the cloud instead of inside of the application on the user's device. For example, there could be a function which would react when there is an image uploaded, this function could do things such as download the image, resize, and cropping it, and then uploading it back into the database. This example is shown in Figure 18. [32]

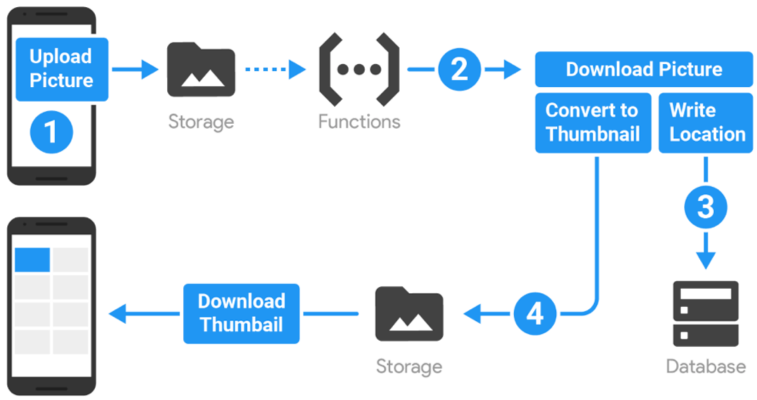


Figure 18 - Cloud Functions Image Conversion

A function like this could be useful for the proposed system, for example, if the user chooses to upload an image for their profile picture, the image might not be the correct size, so the function could resize the image uploaded by the user into the correct size for the application to use.

3.14.3 FaaS Selection

For the proposed system, the Functions as a service which will be implemented will be Google's Cloud Functions. Since the proposed system will implement a Firebase database, cloud functions would be the best choice. Since both are owned and managed by Google there is simple but powerful integration between the two. With AWS Lambda and Firebase, the implementation would not be as simple and straightforward as with the Cloud Functions.

3.15 Music Toolkits

This section will discuss the different music streaming services that provide an SDK (Software Development Kit) for developers to manipulate. Since the Smart Light Hub system will allow its user to stream music from their mobile device. It's imperative that the we provide a solution that is optimal, that gives the user a wide array of music selection options. Not locking the user to a small selection of songs that might not fit their listening preference. After extensive research of streaming SDK, the group has found two options that might working. This section goes into the further detail about Spotify and sound cloud.

3.15.1 Spotify SDK

Spotify is a music streaming service that proving developers the ability to integrating their service into your own projects. The group need to analysis the music stream to get different bins of frequency. To changes the light according and unique feature that Spotify lets you do is access the streamed byte buffer this vital for running transformations algorithms. Since the bytes represent the music in the time domain we need to transform it to the frequency domain. The Spotify SDK is split into two libraries authentication and player [33]. The authentication library is used to get the access tokens to account to verify that the user how the right to use the service. The player library is used for audio playback and streaming management. Also, it works to negotiation with backend Spotify services, manages the digital rights and decoding. For the purpose of our proposed system we will focus on the player library because it allows access the byte buffer that will be transformed to a frequency buffer that will be used to synchronized to the music being played. Something that my become problematic is that the SDK does not allow you to look songs up by its metadata. You have to do this using their web API (Application program interface) after receiving and OAuth token from the SDK [33]. Spotify also provides the developers with an ample amount of documentation and examples for using the SDK. Spotify SDK does not have another issue that could be challenging. Their SDK is still in the beta stages. That being said it's likely that there are some unknown issues that have not being found and resolved. All in all, this SDK seem to provide developers will a large amount of support for projects and it's likely that issues can be resolved quickly.

3.15.2 Sound Cloud SDK

Sound Cloud is another music streaming service that provides developers with an SDK to allow integrating for projects. Another reason for considering the Sound Cloud SDK is because they also allow you to access the streaming audio byte buffer which can be used to transform the time domain bytes to frequency domain. This a vital part of the Smart Light Hub system since one of the core functionality is dependent on music. Although Sound Cloud does not directly provide users with an SDK for android mobile applications there is a third-party SDK available. Some drawback to this since the wrappers were not made by Sound Cloud, the support is not going to be available and we will have to rely on the open source community which may or may not have solutions to potential problem that we might run into. The SDK provides a lot of the feature that will speed the development process up. Since the main focus will on accessing the byte buffer to calculate different frequency bins that will be used to control how the led flash to a particular song.

3.15.1 Toolkit Selection

We have decided to use the Spotify SDK. The following reasons for the choosing this beta SDK for the Smart Light Hub system. The Sound Cloud SDK seems like it will cause a lot of the issues if used as are music streaming backend. We wanted to avoid any porting issue if possible because a great amount of time will be spend developing are frequency analyzer. This will be accomplished by making use of a fast Fourier transform. It supports android mobile platform which thus having this support from the Spotify, makes it easy to resolve issues as they occur. This SDK lets developer access a larger number of music titles. Although, this SDK is in the beta stages Spotify does an excellent job proving an ample amount of documentation. Most importantly they give us access to streamed audio byte buffer. This is essential to our project because we need it to make calculations to understand the frequency of the audio that will be playing in order to flash the led in a rhythmic way.

3.16 Power Consumption Modules

For the purpose of developing the Smart Hub Light System, the team realized that there are different modules and components that require different voltages being supplied. For the ESP8266 Wi-Fi module that was selected, the module requires an input voltage of 3.3 Volts. For the microcontroller chip that was selected, which is based upon the Arduino Uno Development board. The voltage that is required for the microcontroller chip is 5 Volts. To help mediate the situation the team has been looking into different voltage regulators. The voltage regulators allows the team to regulate the voltage to a set voltage value. For example, if the voltage being supplied to the microcontroller is 5 Volts, then the voltage going into the ESP8266 would cause the Wi-Fi module to burn out. To mediate the situation of this, the team would insert a voltage regulator that has a maximum voltage of 3.3 Volts. The output of this coming from the voltage regulator would then be supplied to the input of the ESP8266 Wi-Fi module. The first regulator that will be discussed in this section is the Linear Voltage Regulator.

3.16.1 Linear Voltage Regulator

The Linear voltage regulator is the basic building block of nearly every power supply used in every circuit or component that is found in the real world today. So the way that the linear regulator operates can be found in the figure below.

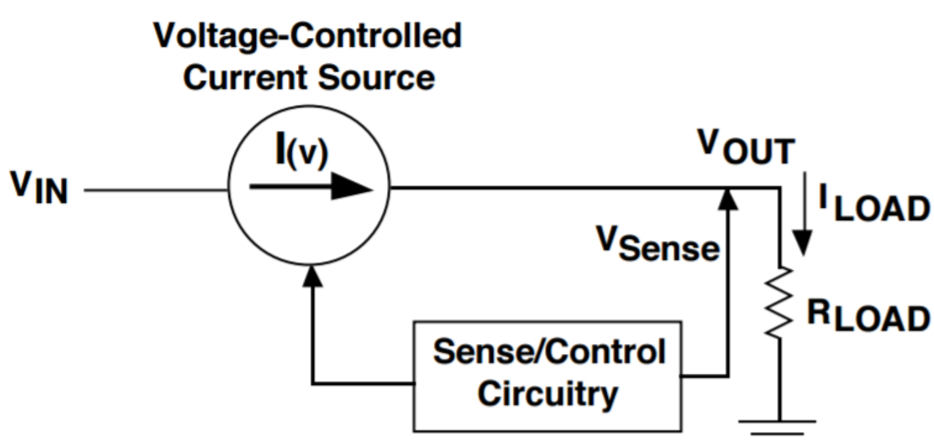


Figure 19 - Linear Voltage Regulator

A linear voltage regulator operates like a voltage-controlled current source to force a fixed voltage to appear at the regulator output terminal. The reason this becomes important is because the overall voltage that is being supplied from the power outlet is roughly around 12 volts. This voltage is too much for the component that are being utilized in the Smart Hub Light System. The voltage requirement for the microcontroller can only handle an input voltage of 5 volts. This means that if the team inserts a linear voltage regulator, then the input voltage of 12 volts, will be dropped down to an output voltage of 5 volts. With the ESP8266 Wi-Fi module, the overall voltage that needs to be supplied is 3.3 volts. If the team supplies more than 3.3 volts, then the overall issue becomes that the ESP8266 Wi-Fi module will burn out. This is not a good scenario for the team because then the team would need to order more Wi-Fi modules. Looking at the figure above, the control circuitry displayed in the figure above must monitor the output voltage and adjust the current source to hold the output voltage to the desired value. The design limit of the regulator in the above figure determines the maximum current load that the regulator can still source while maintaining the output voltage regulation.

Another characteristic of the linear voltage regulator is that it requires a finite amount of time delay to correct the output voltage after a change in the load current occurs. This time delay is the basic definition of the transient response. The transient response is a measure of how fast the regulator returns to steady-state conditions after a load change. The control loop operation of the linear voltage regulator is defined in the overall schematic below.

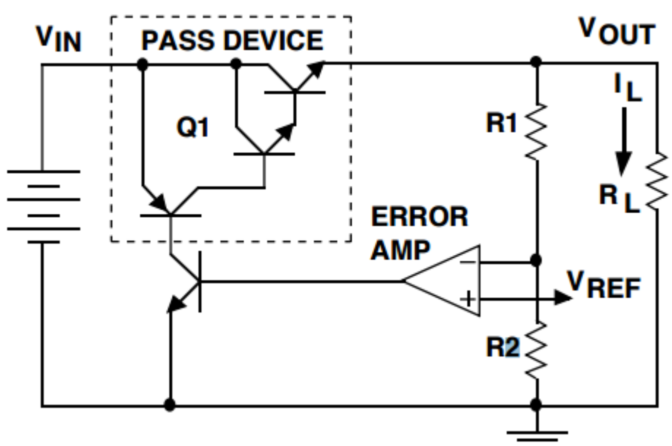


Figure 20 - Control Loop for the Linear Voltage Regulator

The pass device in this regulator is made up of an NPN Darlington driven by a PNP transistor. The current flowing out of the emitter of the pass transistor is controlled by Q2 and the voltage error amplifier. The current through the resistors, R1 and R2 is a current divider that is assumed to be negligible in terms of the overall load current. The feedback loop controls the output voltage that is obtained by the voltages from the two resistors R1 and R2 and takes the output voltage and applies it to the inverted input of the voltage error amplifier. The non-inverting input is tied to a reference voltage meaning that the error amplifier will constantly adjust its output voltage to force the voltages at its inputs to be equal. The feedback loop continuously holds the regulated output at a fixed value which is a multiple of the reference voltage. A sudden increase or decrease in the load current demand will cause the output voltage to change until the loop can correct and stabilize to the new level. The output voltage change is sensed through the two resistors and appears as an error signal at the input of the error amplifier.

There are a few different types of linear regulators that are available in the real world today. The first linear voltage regulator is the NPN Darlington Regulator. The second linear voltage regulator is the Low Dropout or LDO Regulator and the final linear voltage regulator is the Quasi LDO Regulator.

The NPN Darlington regulator uses a pass transistor with a PNP driver that requires that the voltages from the input voltage to the output voltage is maintained in the range of 1.5 Volts to 2.5 Volts for the device to stay in regulation. A figure displaying the NPN regulator can be found below:

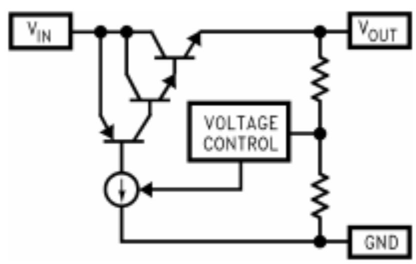


Figure 21 - NPN Regulator Schematic

The next regulator that will be discussed is the LDO (Low Dropout) Regulator. In the LDO linear voltage regulator, the pass transistor is a single PNP transistor. The big advantage of the LDO voltage regulator is that the PNP pass transistor can maintain output regulation with very little voltage drop across it. The figure for the LDO voltage regulator can be found below.

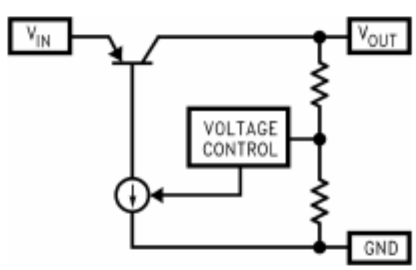


Figure 22 - Low Dropout (LDO) Linear Voltage Regulator

The final linear voltage regulator that will be discussed in this section is the Quasi-LDO regulator. The name for this regulator comes from both of the two previous linear voltage regulators that were mentioned above. The difference is that the Quasi-LDO regulator is half way between both the NPN Darlington regulator and the Low Dropout (LDO) regulator. The pass transistor is made up of a single NPN transistor being driven by a PNP transistor. As a result, the voltage drop for the Quasi-LDO regulator is much less than the NPN Darlington transistor but much more than the Low Dropout (LDO) linear voltage regulator. An image displaying the schematic of the Quasi-LDO regulator can be found below.

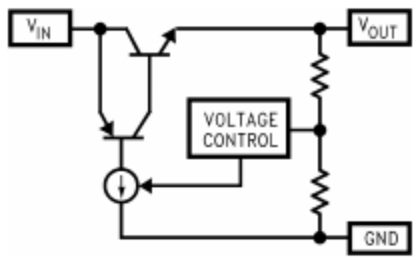


Figure 23 - Quasi-LDO Regulator Linear Voltage Regulator

After looking at the different linear voltage regulators, the team felt that they wanted to research more about different voltage regulators, instead of limiting themselves to the linear voltage regulator. The next regulator that will be discussed in the following section is the Switching Voltage regulator.

3.16.2 Switching Voltage Regulator

A switching voltage regulator is a regulator that rapidly switches a series device on and off. The duty cycle of the switch sets how much charge is transferred to the load. This is controlled by a similar feedback mechanism that can be found in the linear voltage regulator. The reason why the switching regulator is more efficient than the linear voltage regulator is because the series element of the switching regulator is either fully conducting or switched off. This means that the switching regulator does not dissipate any power. The switching regulator is capable of generating an output voltage that is larger than the input voltage. This is one feature that is not possible with the linear voltage regulator.

Now the next step after describing the two voltage regulators is to compare both the linear voltage regulator and the switching voltage regulator. In comparison to the switching voltage regulator, the linear voltage regulator is more suitable for electronic applications when there is a low output noise required. The Linear regulator is better if the developer is trying to get a fast response for disturbances at the input voltage and output voltage. In comparison, however, the switching voltage regulator is the better choice when the power efficiency for an electronic application that wants to consume a low amount of power.

Linear voltage regulators are by far more cheaper and occupy less printed circuit board space than the switching voltage regulator. In comparison, the switching voltage regulator is only applicable if the power supply that is used in the electronic application is a DC voltage. For the switching regulator, it takes in the input current and makes the output current larger. In contrast, the linear voltage regulator takes the input voltage that is being supplied and makes the output voltage lower than the input voltage.

After looking at both the switching regulator and the linear regulator, the team feels that the linear regulator is more suitable for the development of the Smart Hub Light System. The reason as to why the linear regulator is more suitable than the switching regulator is because the goal that the team wants for the regulator is to be able to supply an output voltage that is significantly smaller than the input voltage. The voltage that is coming from the power supply is roughly going to be around 12 Volts. This voltage is not suitable to the Atmega328 chip. The chip can only handle a maximum voltage of 5.5 Volts. So because of that, the team realized that they need a regulator that is capable of providing an output voltage that is smaller than the input voltage. Not only that, but looking at the ESP8266 Wi-Fi module, the module is only capable of handling 3.3 Volts. Because of this the team would also need another voltage regulator that is capable of taking the input voltage and reducing it to output only a voltage of 3.3 Volts. Because of this, the team feels more inclined to select the Linear Voltage Regulator over the Switching Voltage Regulator because the team needs a regulator that is capable of taking the input voltage and reducing the output voltage. The team does not want to use a regulator that will amplify the output voltage because the amplified voltage will damage the entire components that are being utilized on the Smart Hub Light System.

3.16.3 LM7805CT Linear Voltage Regulator

The LM7805CT Linear Voltage regulator is one of the voltage regulators that was selected for the implementation of the microcontroller. The reason why this voltage regulator is necessary is because the regulator helps to regulate the voltage that is coming from the power outlets. The maximum voltage that the ATmega328 can handle is 5 Volts and since the voltage coming from the power outlet is 12 Volts, this regulator is capable of regulating the ATmega328 microcontroller chip. One feature for the LM7805CT linear voltage regulator is that the LM7805CT can handle a minimum input voltage of 7 Volts. This is a good thing for the group because the overall voltage for the power outlets in the United States is 12 Volts. So because the voltage being supplied is higher than the minimum voltage, the module should be able to handle the amount voltage from the power outlet. Another feature with the regulator is that the output voltage coming off of the voltage regulator is 5 Volts. This output voltage is suffice for the amount of voltage that is needed for the microcontroller. The amount of current that is coming out of the voltage regulator is 1.0 ampere. The minimum operating temperature for the LM7805CT voltage regulator is 0 degrees Celsius and the maximum operating temperature for the LM7805CT voltage regulator is 70 degrees Celsius. The load regulation and the line regulation for the LM7805CT voltage regulator is 100 millivolts. The maximum input voltage for the LM7805CT voltage regulator is 35 Volts. None of the components that are utilized in the Smart Hub Light System utilize a voltage higher than 5 Volts. So there should not be any issue with burning out the LM7805CT voltage regulator unless if the component is wired incorrectly. So to ensure that the LM7805CT is wired correctly, the team will utilize the data sheet so that they can ensure that the module does not burn out. A figure displaying the LM7805CT can be found below.

Figure 24 - LM7805CT Linear Voltage Regulator

Looking at the image above, it can be seen that there are three pins on the LM7805CT linear voltage regulator. The pin on the left represents the input voltage pin. This pin will utilize the voltage that is going to be coming from the power outlet or power source. The pin in the middle represents the ground pin. This pin is tied to ground. If you swap the input voltage with the ground pin, you risk blowing the entire LM7805CT linear voltage regulator. The pin on the right is the output voltage pin. This represents the voltage that is going out of the LM7805CT Linear voltage regulator. So if you wire the output pin to ground or to the input voltage, the entire linear voltage regulator will burn out completely. So the team will be utilizing the LM7805CT datasheet as a guideline for wiring the linear voltage regulator correctly.

3.16.4 Crystal Oscillator

In this section, the part that will be discussed here is the crystal oscillator. A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal that is composed of a piezoelectric material to create an electrical signal with a precise frequency. The frequency is used to keep track of the time which will then provide a stable clock signal for digital integrated circuits and to stabilize the frequencies for radio transmitters and receivers. The reason why this is important in the Smart Hub Light System is because the Smart Hub Light System utilizes a microcontroller that will be keeping track of the data that will be sent from the cellular device to the ESP8266 Wi-Fi module. This will also be important for when the LEDs are connected to the microcontroller. In terms of the crystal oscillator, it is a key component in the overall development of the Smart Hub Light System. So there are a lot of crystal oscillator components that are available in the market today. A figure displaying the overall equivalent circuit of the Crystal oscillator can be found below.

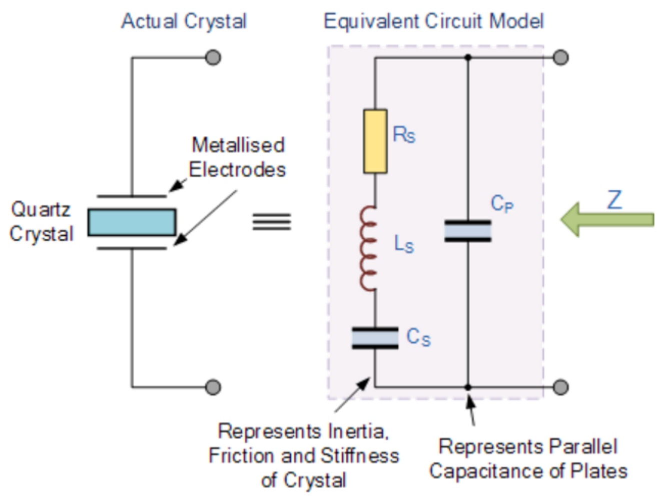


Figure 25 - Equivalent Circuit for the Crystal Oscillator

For the purpose of the Smart Hub Light System, the crystal oscillator that will be used in this project is the 16 Megahertz crystal oscillator. The reason as to why the 16 Megahertz oscillator was selected as the primary crystal oscillator is because the team is using the ATmega328 microcontroller chip. Because they are utilizing this chip, the team realized that the ATmega328 can only process data at a maximum rate of 16 Megaherts per second. A figure displaying the 16 Megahertz clock oscillator can be found below.

Figure 26 - Crystal Oscillator used in Smart Hub Light System

3.17 Project Management Tools

This section discusses the different forms of tools that will be potentially used to manage the development and keep in contact with group members of the Smart Light Hub system. Communication and management is a vital part when working with large group people on a project. It's essential that the group keeps track of who is working on a particular part of the project so we can avoid working on the same thing or even ignoring a part of the project on accident. That would be problematic as the project is on tight timeline because of the summer semester. Therefore, it's important to mitigate any possible management issue by using well defined project management tools.

3.17.1 GitHub

GitHub is a web service that allows developers to manage their code coding project. This is done with several tools they have integrated to the web service. With these services consisting of the following forms of management for code projects. GitHub lets you integrate with slack a popular group chat service, they let you manage different tasks assigned to different people on a project with issues, and has code review tools built into their web service.

GitHub allows slack integration, which is a tool used for communication. This integration allows the team to be notified when anything changes in our GitHub repository. For example, if there is a pull request, commit event, issue event, or deployment statuses update a notification will show up in the slack channel associated with that repository.

These are some essential features when working on a larger project were everyone is not working on code it allows for other member see how much progress is being made so they do not have to worry about work being completed.

Another feature that GitHub has is tracking tasks with issues. Issues allows different members working on code to be assigned to different tasks. Also track how the progress of that tasking is going as well as let member on the group know when its task has been completed. This becomes apparent to member on the group when an issue is closed. When an issue is closed that means that task has been completed.

Finally, the last project management tool that will be discussed that GitHub has to offer is code review. Code review by GitHub allow for other member of the group to make comment on the code written by other members to give them constructive feedback. This feature as allows you to resolve code conflicts. Which can be overwhelming when working on a large-scale project. These functionalities are vital when working on large projects and different people of the different experience levels. Helps strengths member skill and learn new ways to approach new problems and best practices. All the features mentioned provide a way of making coding process seamless.

3.17.2 Google Suite

Google Suite is a set of applications to allow teams to better work together seamlessly, from any device. They have many products and services, Google Drive, Email, Docs, and Calendars were the services primarily used for this project. [34]

Google Drive is primarily a cloud storage platform which can be used to store files of multiple different formats and allow others access to those files. With this tool, the group can and has been able to stay organized and share files easily, by having them all on the Google Drive. [35]

Along with cloud storage Suite has multiple different features. Such as team communication. When an email needs to be sent out to all our team members, implementation of Google Email Groups has come in very useful, this feature allows creation of an email list, thus saving time of adding the recipients email addresses every time an email needs to go out. A group email is sent out to everyone in the group, thus ensuring everyone is always up to date, content such as calendars and drive documents can be send to all members. [35]

Another feature implemented by our team is the use of Google Docs. When our team needs to collaborate, and write, such as this project proposal, it can seamlessly be done using Google Docs. This allows all tem members to have access to the most up to date document, since the document updates in real time. We can leave comments, see who content was written by, and chat with group members in the document. [35]

To ensure our team our team could schedule efficiently, Google Calendars were used. With this feature each member had access to the most up to date calendar for all the team. Each member put their work and class schedule in the document, thus allowing us to find the optimal time to schedule meetings with the entire team as well as our sub teams. [35]

3.17.3 Trello

Many collaboration tools will be used for this project, I order to manage, and ensure that all members are doing their part and that the project is progressing. Trello is one of those tools, it is a collaboration tool which helps organize projects by placing task into boards. These boards can say or represent anything the user wants, but typically they are meant to show what needs to be done, what's currently being done and what has been completed. The organizations of the boards for our project were broken down into Hardware, Software, Doing and Done, as shown in Figure 27.

In the Hardware board, task which have yet to be started for the hardware portion of the project are listed. These tasked are assigned to one of two members on the hardware portion of the project. These two members will completely manage that portion of the project, including what goes on the Hardware Trello Board. As new task arrives, they will be added to the board, anything ranging from research to development will be listed.

Similar to the Hardware Board, the Software board shows the task which have yet to be started from the software side of the project. These tasks and this board will be managed completely by the two members of the software portion of the project.

The Doing board show what is currently being worked on by both teams, and the Done board shows what has been completed by both teams. These boards will not be separated into Hardware or Software to show what has been completed in the project all around, thus providing an idea of what stage the project is in, and how close to completion it is.

There are many other project management tools like Trello available, but Trello was selected for our project because of all its additional capabilities with our other project management software. For example, GitHub is used to manage the code for this project, Trello has a GitHub connection. With this GitHub connection we can attach branches, commits, and pulls request directly to the cards made in Trello. This will save other team members from having to go to GitHub to track progress on an issue. There's also a Slack connection, which enables attaching and sending Trello cards directly through slack channels. So, members don't necessarily have to navigate through Trello, the card can be send to them through the Slack Channel. The last connection used for this project is the Google Drive connection, which allows us to attach our Google Drive files directly to the Trello Card. So, members can see the task to be completed as well as any file associated with that task. [36]

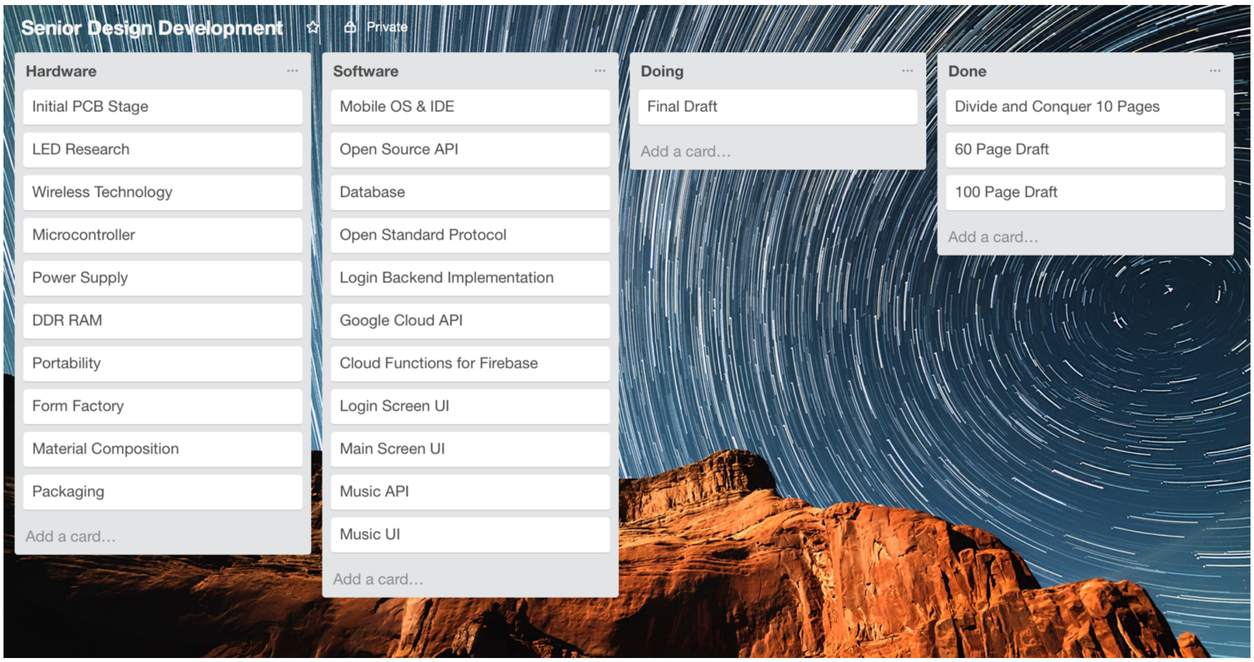


Figure 27 - Trello Boards

3.17.4 Slack

Slack is a communication platform, with the primary function being allowing teams to communicate through messages. Slack is better than general text messaging since it offers an in-browser option, desktop application and mobile application. So users can send messages from their computers instead of on their mobile device. The real benefit of the access on the computer comes with the file sharing capabilities with slack. Users can simply drag and drop a file into the slack application and send it to another user. This application also has integration with google drive, so you can search through the files without leaving the application.

Slack has a feature called Channels, this allows a team to have multiple channels to communicate through. Our group has three channels, Hardware, Software, and General. The Hardware channel is comprised of the two hardware team members for the project. They can share files and communicate about topics specifically pertaining to their subject matter. Conversely, the Software channel is comprised of the two software team members. The other members can still access these channels to see the full chat log, but won't be actively notified or expected to respond to messages outside of their teams. For complete group communication, about topics pertaining to all aspects of this project, the General Channel is used for communication. [37]

3.17.5 Skype

skype is a communication service that let you make webcam calls, send text messages or call people over the internet. How can this be used to manage a project? It can be used in the following ways to do so. skype allow users to have meeting without having to physically meet. They can meet over the internet via webcam. This can be useful when you are working with a group of people who do not live close by or even works at a different location if the same company. Skype allows for its users to share their screen this be can be extremely useful when working on a code review with one of your group members or even when you're working on PCB design. Along with screen sharing the users can take control of another member computer system to provide them with more hands help which can be helpful when working remotely. Also, skype comes free with a copy of office 365, with the integration of 365 you can share PowerPoint slide to give a presentation at a meeting remotely. Skype provides its member with a wide array of project management tool. With these tools, it makes it possible to collaborate in a more effective way that be drive your project to it goals of being complete in a time manger.

3.17.6 Git Version Control

The software team implemented the use of Version control, the use of this is good programming practice to help ensure the code for the project was secure. Version control is a system which keeps a record of all the changes that occur amongst a file or multiple files. This record allows users to be able to go back to older versions of their files. This helps to allow developers to go back to a working state of their files, if they saved a corrupted file. There are a few different systems being, local, centralized and distributed version control systems. For this project, the distributed version control system (DVCS) was used. [38]

Git, which is a form of a DVCS, works by allowing clients to check out the latest copy of the files, which usually resides on a server. This allows each user to have a local copy, with this local copy the user can make changes to the files and then push them back onto the server. [38] A "Commit" saves a user's local changes, and with a "Push", the user can store those changes on the server. With Git, each user can have a different branch to work in, allowing their changes to not interfere with another user. This is useful when a branch is used for a different aspect of the project. For example, one branch can be LED programming, while another is Music Controls.

Once the user has pushed their changes to their branch, a “Pull Request” can be made, this allows a user to “Merge” their changes with the master branch. The Master branch store the files with all changes merged together.

Having a DVCS has a major benefit, if the file on any of the servers, whether on the user’s local machine, or the main server gets lost or corrupted, since there are multiple copies, it can be restored. [38]

3.18 ATmega Setup

This section will focus on some of the preliminary requirements to programming and developing with the Arduino. Generally, a programmer is used to program a microcontroller, unless a there is a bootloader in the microcontroller. A bootloader allows the installation of new firmware. An in-system programmer is required to burn the bootloader. [39]

Burning the bootloader is the first step in mitigating from just an Arduino board to a standalone microcontroller on a breadboard. For the proposed project the ATmega328 is used, so the bootloader will be burned onto it. The Arduino Uno will be used as the in-system programmer. Once the ATmega has been programmed the Arduino will no longer be required for the system. [40]

3.19 Summary of Components for Smart Hub Light System

In this section, the team will dive into the components that they have ordered for the Smart Hub Light System. This step is an important part of the research section because it verifies that the team has actually ordered their components for the Smart Hub Light System. This last section of the research section verifies that the team has actually been keeping up and meeting their milestones for the project. The table found below lists all of the Key Components for the Smart Hub Light System:

Table 5 - List of Components Ordered for Smart Hub Light System

Components Ordered	Cost of Component	Number of Components Ordered
Atmega328 Microcontroller	$13.49	3
Adafruit Industrial 1138 Digital RGB LED	$30.77	1 (60 LEDs one meter long)

ESP8266 Wi-Fi Module	$15.99	4
28-pin IC Chip Socket Adapter	$10.35	10
LM7805CT Voltage Regulator	$5.38	2
16 MHz DIP Quartz Crystal Oscillators	$10.48	10

Looking at the table above, it can be seen that the team has ordered most of the major components for the Smart Hub Light System. The microcontroller listed in the table above is based on the microcontroller that is found on the Arduino Uno Shield. The crystal oscillators are a key component for the Smart Hub Light System because it provides a clock for the microcontroller. The reason as to why this is important is because in the case of the microcontroller, it contains two pins that are dedicated for the crystal oscillator. Because of the dedicated pins on the microcontroller, it allows for the excitation of the crystal oscillator which allows for the overall processing of the data packets coming into the microcontroller. The key for the crystal oscillator is that once it is implemented, it must be implemented with a circuit. So in the hardware testing section, the team implemented a circuit that utilized two 22 picofarads capacitors. This allowed for the clock oscillator to process the data that was coming into the overall microcontroller. The good thing is that since the crystal oscillator is a 16 MHz oscillator, then the speed at which the microcontroller can process the data is at 16 million times per second, which is pretty fast when compared to the computing standards for CPUs that are found in electronic devices. The 7805CT voltage regulator is an important component for the Smart Hub light System because it helps to regulate the voltage that is going across the 10 uF and 0.1uF capacitors. The reason as to why the voltage regulator is inserted between the power LED is because the voltage regulator regulates the amount of voltage that is going into the LED circuit. The Output voltage for the regulator is significantly smaller than the input voltage which means that the group is dealing with a Linear Voltage Regulator. The reason why the DIP IC Chip socket adapter is an important component is because it helps to shield the microcontroller from the electro-static discharge. Another reason as to why the chip socket adapter is important is it allows the team to have a more formal way of presenting their printed circuit board design, which allows for the user to understand the overall layout of the Smart Hub Light System. The Adafruit LEDs are a major component for the Smart Hub Light System because it’s the component that will be used to create different patterns from the user’s cellular device. The reason as to why the LEDs are a component is because the LEDs are easily compatible with the microcontroller that is utilized in the overall development of the Smart Hub Light System. The last major component found in the table above is the ESP8266 Wi-Fi module. This module is important in the development of the Smart Hub Light System because it serves as the main communication between the overall microcontroller and the cellular device. The Wi-Fi module was selected based on the criteria that was found in the tables in the above sections. The overall reason why the team wanted this specific Wi-Fi module is because the team felt that the overall design of the Smart Hub Light System was well suited to the ESP8266 Wi-Fi module. Because of this, the team ensured that they ordered extra modules because the team realized that these modules are easy to burn out. As to why the modules burn out, well the reason is because most users who develop different applications for the module often forget to look at the datasheet. Usually what happens after users implement this module is that they start to smell smoke and the module when touched is extremely hot. Because of this, the team took extra precaution in ensuring that none of the modules would be burned out. In the figure below, the team is going to show the different components that were ordered for the Smart Hub Light System.

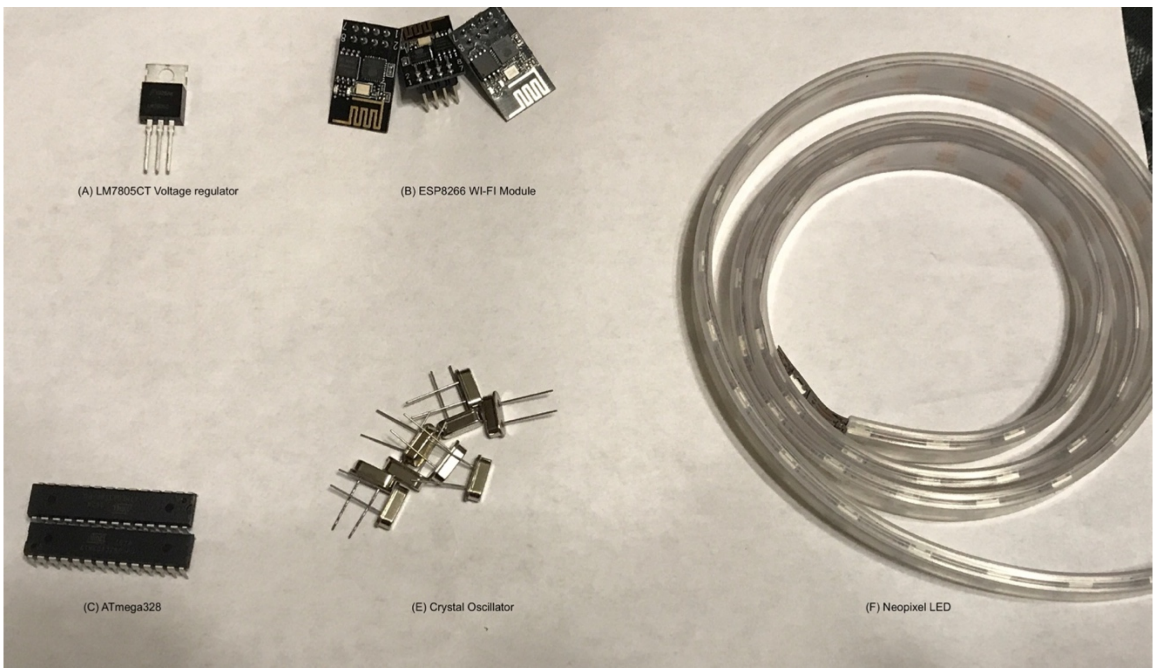


Figure 28 - Major Components

4.0 Related Standards and Design Constraints

In this section, design standards and design constraints are discussed throughout the section. It's imperative to the understand what standards will affect our project. this section goes into great detail about the different standards that will affect are project. Also, understand how different types of constraints will affect are project as well. All of these factors need to be realized earlier in the in the research process to make sure what is being designed is not breaking any of the standards that were put in place to guide engineers to make good decisions.

4.1 Related Standards

In this section, it will discuss about the different standards which impact the build of the Smart Light Hub system. Standards are documents which explain regulations that have been put in place by companies that have spent many years studying the impact a technology may have on a person safety, the environmental implications and reliability on certain technology. Standards also help by making it easier to deliver a project from the proof of concept to the final product dramatically because engineers do not have to worry about the many impacts. This time savings is very beneficial because a group of engineers can focus on using those standards to create new technology. These standards are unusually crated by IEEE, ASNI and other entities.

4.1.1 802.11 Standard

The 802.11 standard is a wireless standard documented by the institute of electrical and electronics engineering. Its purpose is to standardize the access to different frequency bands and provide wireless connectivity for fixed, portable and moving stations within a local area. [26] Since our project relies on a wireless communication having this standard in place we can focus on the implementation of using the standard to communication with the different subsystem of the Smart Light Hub.

4.1.2 Android Development Guidelines

Since are project will implement an android application we will following the guideline provided by google. The guidance provided by google are fundamental concepts a developer should know when developing an android application. Although these guidelines are not mandated standards that need to be followed, they serve more as best practices for implementing an android application. By following these guidelines, we can guarantee a quality mobile application. Google has also provided developers with core quality guidelines. The areas of interest by the guidance provided are visual design and User interaction, functionality, compatibility, performance and stability, security and test procedures. When design our application we will be focusing on these main functionalities that can be identified by this ID number for each category.

Table 6 -Android Guidelines

Visual design and user interaction	
Standard ID	Description
UX-B1	Provides guidance for designing user interface for best user experience
UX-N1	Recommends where to place back button
UX-N2	Recommends how to dismiss popup dialogs
UX-N3	Describes how the home button should work at any point while using an application
UX-S2	Recommends when an application should use notifications
Functionality	
FN-P1	Recommends that an application only requests a minimal amount of resources to run
Compatibility, performance and stability	
PS-V1	Recommends that an application displays all the comments of an application without have noticeable misrepresentation, distorting or pixilation.
PS-V2	Describes how text and blocks of text show be displayed
Security	
SC-D4	Recommends that logging of personal and sensitive data should not be logged to the system
Test procedures	
SC-1	Recommends that the process of storing data externally is review
CR-0	Recommends how to test the all navigation component of the application

4.1.3 Programming Standards

Programming standards are conventions used by software engineers to make code constant to allow for multiple developers to work on the same software assignment. These guidelines are used to better structure code written by developer. For the Smart Light Hub system, we be adhering to the following intention, commenting and naming conventions.

Table 7 - Programming Standards

Convention	Description
Allman	Allman intention style is when braces for control statements are on the same level.
End-of-line	The end-of-line method of commenting starts with // and the remaining of the line is considered a comment until the end of that line. This is our opinion provides a clean look when commenting code.

Since we be using an objected oriented language will make use of a few naming conventions to quickly identify and differentiate core components of the software. the **Table 8** below has the component and a description how naming the component will be done.

Table 8 - Programming Standards II

Component	Description
Classes	We will be using upper camel case example: PlayMusic
Methods	We will be using lower camel case example: stopMusic
Variables	This will also use lower camel case
Constants	Will be in all uppercase and separated by underscores example: LED_STATE

4.1.4 PCB Standards

Printed circuit boards standards are defined by IPC, the Association Connecting Electronic Industries. They standardize manufacturing and requirements of the electronics equipment in assembling. This trademark association is accredited by ANSI, American National Standards institute. There are many standard that IPC produces to make sure every company manufacturing PCB have guidelines to follow to. These procedures allow for consistency when manufacturing PCB's to ensure that buys are going to receive the same quality no matter where it may have been manufactured. The standards include general design, documents, specifications, material specifications, performance and inspections documents, and flex assembly and material standards. One of the IPC standards is the IPC-2221B which focuses on printed board design. IPC-2221B lays out the requirements for the PCF design and where the components are mounted. The IPC-2220 standard covers the PCB design in CAD. This standard is built around the IPC-2221B standard and uses the requirements for printed circuit board design in the software. The next standard is the IPC-2223 which discusses about the sectional design standard for flexible printed boards. There are also other standards in this area which focus on spacing between the PCF boards, the current bearing requirements of the traces, material properties, tolerance rules, and conductor thickness. The IPC-7351B is the generic requirements or surface mount design and land pattern standards. With these standards it helps the design achieve the desired results. The standards control over the product quality and reliability which are important of competing in the marketplace and to the products profitability. By using the IPC standards throughout the design process, longer life, cheaper cost, and better performance can be ensured. The benefit of working from an established IPC standard is that people from all over the world can work together. When the design complies with IPC standards allows the designer to create electronic assemblies that meet quality test which minimizes costs. [41]

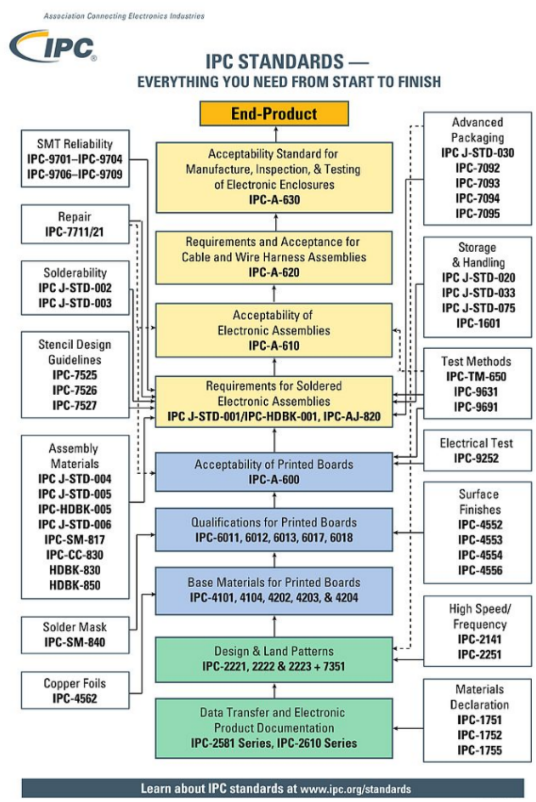


Figure 29 - IPC Standards

4.1.5 LED Standards

With the development of the Smart Hub Light System, one of the key elements of this system is the utilization of LED lighting. Because the team is utilizing LEDs, there are a few standards that the team has researched in thus far. One of the standards is Zhaga. Zhaga is an industry-wide consortium aiming to standardize specifications for interfaces between LED luminaires and light engines. The aim is to permit interchangeability between products made by different manufacturers. Zhaga defines test procedures for luminaires and LED light engines so that the luminaire will accept the LED engine. There are also standards for LEDs that are defined by Energy Star Specifications. The first specification is referenced by ANSI (American National Standard Institute) which establishes definitions of solid state lighting devices and components. It also provides a common terminology. The next specification is IESNA (Illuminating Engineering Society of North America) which provides procedures for reproducible measurements of photometry, color and electrical characteristics of solid state lighting products. The next specification of the Energy Star specification is UL (Underwriters Laboratories) which writes safety standards for LED products including drivers, controllers, arrays, packages and modules. The final specification of the Energy Star specification is NEMA (National Electrical Manufacturers Association) which makes recommendations for mechanical, thermal and electrical interfaces between luminaires. Another Industry standard is CELMA. CELMA is the Federation of National Manufacturers Associations for Luminaires and Electrotechnical components in the European Union. CELMA along with ELC, - (European Lamp Companies Federation) provides standards and guides for LED lighting in Europe. Another Industry standard for LEDs is IP (Ingress protection) ratings or UL (Universal Laboratories) ratings are commonly used to determine LED product suitability for various harsh, underwater or outdoor applications. Another standard that is often looked into for LEDs is light fitting. In Europe, every light fitting must have a CE label. This tells you that the seller claims that the fitting conforms to all the relevant European safety standards. The most important of these is EN 60598 which covers electrical, thermal and mechanical safety. Another standard for LEDs is PAS. PAS is Publicly Available Standard, an informal rating-used in Europe. Whilst it is not a formal EN standard, it is an industry-agreed way of presenting data and procedures. Another standard for LEDs is the UL 8750. Inside the UL 8750, it states that these requirements cover LED equipment that is an integral part of a luminaire or other lighting equipment and which operates in the visible light spectrum between 400 - 700 nm. These requirements also cover the component parts of light emitting diode (LED) equipment, including LED drivers, controllers, arrays, modules, and packages as defined within this standard. It also states that these lighting products are intended for installation on branch circuits of 600 V nominal or less in accordance with the National Electrical Code (NEC), ANSI/NFPA 70, and for connection to isolated (non-utility connected) power sources such as generators, batteries, fuel cells, solar cells, and the like. LED equipment is utilized in lighting products that comply with the end-product standards listed below. The requirements in this standard are intended to supplement those in other end-product standards. Included are

Electric Signs, UL 48, Portable Electric Luminaires, UL 153, Underwater Luminaires and Submersible Junction Boxes, UL 676, Emergency Lighting and Power Equipment, UL 924, Stage and Studio Luminaires and Connector Strips, UL 1573, Track Lighting Systems, UL 1574, Luminaires, UL 1598, Direct Plug-In Nightlights, UL 1786, Low Voltage Landscape Lighting Systems, UL 1838, Self-Ballasted Lamps and Lamp Adapters, UL 1993, Luminous Egress Path Marking Systems, UL 1994, and Low Voltage Lighting Systems, UL 2108.

Another standard for LEDs is the energy efficient standard. The energy efficient standard for the United States is the ASHRAE 90.1. ASHRAE 90.1 can be considered the standard energy code for the United States. The federal Energy Policy Act of 2005 (EPAct), as amended, requires that states adopt an energy code at least as stringent as whatever edition of ASHRAE 90.1 is found to be most stringent by the Department of Energy (DoE). Title 24, directly enforceable only in California, operates to some degree as a bellwether code—significant changes to ASHRAE 90.1 and IECC often appear first in Title 24 and then migrate to future editions of the other two codes. These codes and their predecessors can exert substantial influence on lighting markets. For example, California Title 20, 1605.1(l), included by reference in California Title 24, requires that exit signs consume no more than 5 W per face, echoing the requirements of the EPAct. That level is difficult to achieve with fluorescent lamps, and impossible with incandescent lamps. The requirement had the effect of creating a de facto requirement for LED drivers in exit signs. Today, practically every exit sign uses LEDs as its light source. The primary intent of the codes is to ensure that the built environment uses less energy than it would in their absence. One of their secondary purposes is to foster technologies that show promise for future energy conservation. LED lighting currently looks to be one of those technologies, and we can expect the codes to include requirements that foster its development and acceptance to the extent that those requirements are reasonably achievable and don't conflict with the codes' primary purpose.

In terms of the amount of allowable lighting power densities for LEDs, there is a standard for this. The standard states that the allowable lighting power densities of the codes are approximately aligned with one another. Allowable densities are generally reduced from previous versions, but not dramatically, as the code-makers have become concerned about maintaining the quality of the indoor environment at low lighting power levels. Consequently, most of the improvement in buildings' lighting efficiency will come from enhanced control requirements, rather than lighting power density limits. The prescribed levels are roughly as achievable with fluorescent lighting as with LED, though high-end LED fixtures may provide a bit better headroom.

4.1.6 Power Standards

Another standard that the team must consider is the power standards. Because the Smart Hub Light System is going to be powered via either by battery or by a power supply. So to start off, when looking at power standards, the table below explains the different types of circuit definitions below.

circuit Voltage Standards	
Hazardous Voltage	Any voltage exceeding 42.2 Vac peak or 60 Vdc without a limited current circuit
Extra-Low Voltage (ELV)	A voltage in a secondary circuit not exceeding 42.4 Vac peak or 60 Vdc, the circuit being separated from hazardous voltage by at least basic insulation.
Safety Extra-Low Voltage (SELV) Circuit	A secondary circuit that cannot reach a hazardous voltage between any two accessible parts or an accessible part and protective earth under normal operation or while experiencing a single fault. In the event of a single fault condition (insulation or component failure) the voltage in accessible parts of SELV circuits shall not exceed 42.4 Vac peak or 60 Vdc for longer than 200 ms. An absolute limit of 71 Vac peak or 120 Vdc must not be exceeded. SELV circuits must be separated from hazardous voltages, e.g. primary circuits, by two levels of protection, which may be double insulation, or basic insulation combined with an earthed conductive barrier. SELV secondaries are considered safe for operator access. Circuits fed by SELV power supply outputs do not require extensive safety testing or creepage and clearance evaluations.
Limited Current Circuits	These circuits may be accessible even though voltages are in excess of SELV requirements. A limited current circuit is designed to ensure that under a fault condition, the current that can be drawn is not hazardous. Limits are detailed as follows:

	• For frequencies < 1 kHz the steady state current drawn shall not exceed 0.7 mA peak ac or 2 mA dc. • For frequencies above 1 kHz the limit of 0.7 mA is multiplied by the frequency in kHz but shall not exceed 70 mA. Δ For accessible parts not exceeding 450 Vac peak or 450 Vdc, the maximum circuit capacitance allowed is 0.1 μF. • For accessible parts not exceeding 1500 Vac peak or 1500 Vdc the maximum stored charge allowed is 45 μC and the available energy shall not be above 350 mJ.

The International Electrotechnical Commission (IEC) and the associated International Organization for Standardization (ISO) are the principle agencies responsible for electrical safety standards. Agencies such as Underwriters Laboratories (UL) and Canadian Standards Association (CSA) provide certification in North America, while similar bodies in Europe are Verband der Elektrotechnik (VDE), Technischer Überwachungs-Verein (TUV) and British Standards Institution (BSI). A product meeting an IEC standard such as IEC60950 may be identified with the standard's number prefixed instead by UL, CSA or EN (European Norm) to indicate the country where it is certified e.g. UL60950 or EN60950. Standards like these with the same numbers but different prefixes are sometimes referred to as "harmonized standards". But while the IEC continues to pursue harmonization, regional differences remain and consequently products intended for multiple markets will need to show all the required certifications. There are also several classes that are based on different applications of powering different components or appliances in the world. IEC60950-1 consolidates the 2005 2nd edition of this standard with its first and second amendments (from 2009 and 2013 respectively). The standard is applicable to mains, or battery-powered information technology (IT) equipment and office machines with a rated voltage not exceeding 600 V. It is intended to prevent injury and damage to persons and property from such hazards as electric shock, fire, dangerous temperatures and mechanical instability. Note that in Germany this standard is also referenced as DIN EN60950-1 and as VDE0805. Class 1 equipment achieves electric shock protection through basic insulation and protective earth grounding. This requires all conductive parts that could assume a hazardous voltage in the event of basic insulation failure to be connected to a protective earth conductor. Class 2 equipment provides protection using double or reinforced insulation and hence no ground is required. Class 3 equipment operates from a SELV (Safety Extra Low Voltage) supply circuit, which means it inherently protects against electric shock, as it is impossible for hazardous voltages to be generated within the equipment.

4.1.7 IEEE 830-1998

Since the group will be designing a system that uses software another standard that we will follow is IEEE 830 - 1998. Also, known as the recommended practice for software requirements specifications SRS for short. SRS is used to the describe the process of creating a product and the content of the product [42]. SRS has eight different clauses to consider when to produce a good product. Which will be discussed at brief the nature, environment, characteristics, joint preparation, evolution, prototyping, embedded design, and embedded project requirements.

Table 9 - SRS

Nature	The software being deign will let user easily interact with their home lights. people with interact with the system using a mobile application. The general performance of the system should be relatively quick. The system is composed of three major subsystems that's a mobile application, a hub, and a lighting system. Since the entire system can be controlled over a user's home Wi-Fi we need to provide a secure way for allowed users to control the system.
Environment	The software of the system will be used to drive all the major subsystems to provide the user will a completely new experience. With the final software component working seamlessly by the end of the project.
Characteristics	When designing good software requirement, it should be a correct, unambiguous, and complete. It must also be consistent stability and verifiable. Also, modifiable and traceable.
Joint preparation	Since we do not have an actual customer we cannot perform this section of SRS, because this section is where the customer and people that going to the suppling the software work together to prepare requirements.
Evolution	This section describes how the requirement can be changed at point and the stipulations to do so. if the SRS is to be modify their need to be a paper trail with different version numbers. When revision are made, it must be approved.
Prototyping	Prototyping is done to provide the customer with some type of characteristics of the application so that feedback can be given quickly, so the desired changes to the requirement can be made. This is done because the customer most likely does not have a technical background. Prototyping helps to reduce development time.

Embedded design	The section discusses how the code will be written. How the break the code into modules to make testing of these components easy. Also describing the how to control the modules and how to store the data use by the application.
Embedded project design	This section of the SRS does not describe anything pertaining to the software component of the system but rather the process to make the product an and focus mostly on these elements • Cost • Delivery • Reporting procedures • Software development methods • Quality assurance • Valid and verification • Acceptance procedures

4.1.8 Soldering Standards

The soldering standards is another important standard that will be discussed because of the implementation of the LED lights. The J-STD-001F standard lists a set amount of requirements for Soldered Electrical and Electronic Assemblies. This standard prescribes practices and requirements for the manufacture of soldered electrical and electronic assemblies. Historically, electronic assembly (soldering) standards contained a more comprehensive tutorial addressing principles and techniques. For a more complete understanding of this document's recommendations and requirements, one may use this document in conjunction with IPC-HDBK-001 and IPC-A-610. The minimum spacing between noncommon uninsulated conductors (e.g., patterns, materials, hardware, residue) is referred to as "minimum electrical clearance" throughout this document and is defined in the applicable design standard or on the approved or controlled documentation. Insulating material needs to provide sufficient electrical isolation. In the absence of a known design standard use Appendix B (derived from IPC-2221). The solder destination side is that side of the printed circuit board (PCB) that the solder flows toward in a plated-through hole application. The solder source side is the side of the PCB tohich solder is applied. This standard is very limited in its applicability to the manufacturing processes associated with the mounting of internal electronic elements and the soldering of the internal connections of transformers, motors, and similar devices. Unless a user has a specific need for the controls provided by this standard, it should not be imposed relative to the manufacture of the internal elements of these devices.

4.1.9 Standards on the Insulation of Wires

The design of the Smart Hub Light System will contain different components that will need to be wired in a small and concise manner. The overall insulation of the wires will be an important factor that the team will need to consider because the team does not want to have any components short out. ASTM's insulating material standards are instrumental in specifying, evaluating, and testing the electrical and physical properties of materials used primarily as electrical insulation in devices and related equipments. These properties include dielectric breakdown voltage, dielectric strength, AC loss, permittivity (dielectric constant), DC resistance and conductance, dissipation factor, ion exchange capacity, ionic resistivity, and other physical properties. These electrical insulating material standards allow manufacturers, particularly those in the semiconductor industry, to examine and assess such materials and equipments to ensure their qualification for safe use. The UL 758 Standard for Appliance Wiring Material states that these requirements cover Appliance Wiring Material (AWM) in the form of single insulated conductors, multi-conductor cables, optical fibers, individual insulated conductors, and fiber optic members for use as components in multi-conductor cables. The appliance wiring material covered by the requirements of this Standard are solely for use as factory-installed wiring either within the overall enclosure of appliances and other equipment (internal wiring) or as external interconnecting cable for appliances (external wiring), or for further processing as components in multi-conductor cables. These requirements do not cover any wire, cable, or cord types that are presently covered in the National Electrical Code (NEC), NFPA 70, and are not intended for installation in buildings or structures in accordance with the NEC except within the scope of the installation instructions of the end-product for which their use is intended. These requirements cover appliance wiring material with operating temperatures from a minimum 60°C (140°F) dry temperature rating and voltage ratings from a minimum 30-volt rating. Conductor size ranges from 50 AWG to 2000 kcmil. Appliance wiring material (AWM) composed entirely of optical fiber members or electrical conductors in combination with optical fiber members are also covered by these requirements. These requirements do not cover the optical performance of any optical-fiber member or group of such members. These requirements do not cover constructions which utilize flat, insulated conductors that are not laid parallel. The requirements for these products are found in the Standard for Flexible Materials Interconnect Constructions, UL 796F. The evaluation of the performance of the semi-conductive polymeric layer described in 5.9 is not covered by this Standard. In addition to these constructions, this Standard establishes guidelines for the evaluation of special constructions that, due to their specific end product use, are not required to meet all of the requirements for general construction AWM. The final acceptance of AWM is dependent upon its use in complete equipment that conforms with the standards applicable to such equipment.

4.1.10 Microcontroller Standards

The next standard that will be covered will be the microcontroller standards. The reason why this standard is important is because the microcontroller will be a vital part of the Smart Hub Light System. A standard developed for the Microcontroller is the AN901 Standard. The use of microcontroller-based systems is increasingly wide-spread, especially in such areas as consumer, industrial and automotive applications, where the drive for cost reduction is the common trend. This emphasis on cost reduction and the increasing complexity of such systems requires the manufacturers of semiconductor components to develop highly integrated, single chip, high operating frequency microcontrollers using the highest density technology possible. Unfortunately, for semiconductor structures, the higher the density and the faster the operation, intrinsically the higher the level of electrical noise generated, and the increased sensitivity to spikes induced from external noise. Therefore, the PCB layout, the software and the system must now apply EMC “hardening” techniques in their design.

Electrostatic discharges, mains, switching of high currents and voltages or radio frequency (RF) generators are just some of the causes of electromagnetic interference, or noise, in microcontroller environments. Within the microcontroller itself, the main contributors to noise are: oscillator continuous RF source, system clock circuits RF divider followed by large amplifiers which drive long lines inside the component, output transitions the relative weight depends on the frequency of the transitions and their duration; i.e. the shorter the transitions, the richer the frequency spectrum, data/address buses for some microcontrollers, a part of the memory space is external, which implies continuous transitions on several lines.

For technical reasons, it is best to use a multi-layer printed circuit board (PCB) with a separate layer dedicated to the ground and another one to the VDD supply, which results in a good decoupling, as well as a good shielding effect. For many applications, economical requirements prohibit the use of this type of board. In this case, the most important feature is to ensure a good structure for the ground and power supply. A preliminary layout of the PCB must separate the different circuits according to their EMI contribution in order to reduce cross-coupling on the PCB, i.e. noisy, high-current circuits, low voltage circuits, and digital components. The GROUND should be distributed individually to every block (noisy, low level sensitive, digital,...) with a single point for gathering all ground returns. Loops must be avoided or have a minimum surface. The power supply should be implemented close to the ground line to minimize the surface of the supply loop. This is due to the fact that the supply loop acts as an antenna, and is therefore the main emitter and receiver of EMI. All component-free surfaces of the PCB must be filled with additional grounding to create a kind of shielding (especially when using single-layer PCBs). Almost all microcontrollers have an oscillator coupled to an external crystal or ceramic resonator. On the PCB, the copper traces to pins EXTAL/XTAL/VSS (for external capacitors) must be kept as short as possible. These capacitors are included in certain resonators which further shorten traces. Since the RC option is potentially sensitive to spikes which can shorten clock periods, the resonator option is preferable. With a programmable system, an obvious possible EMS weakness arises from an unique process that relies on valid memorized data. At first, the unique process must be split into as many parallel and independent processes as possible. This is particularly important for security functions such as the watchdog, refresh routine and the initialization routine. Additionally, such a split is useful for locating weaknesses during

EMC debugging. In many cases, the internal program space is not used 100%. This creates a free memory area where normally, the application program must never take instructions. This area must be used as a trap which leads to a Reset routine. This is done by filling this area with No-Operation instructions (NOPs) followed by a “JUMP to Reset Routine” command. Surface-mounted components (SMCs) have a higher density than standard through-hole mounted components, and therefore require shorter traces on the PCB. For microcontrollers, SMC packages such as small outline (SO) and quad flat (QFP) packages reduce the length of signal lines and require a smaller power supply loop.

4.2 Design Constraints

In this section, it deals with the design constraints and how it can affect the design of the Smart Light Hub. These constraints affect the development of smart light hub system and it adapted from the standards from previous studies and intensive research. When design a system a group of engineers must consider the following This section of the paper will discuss the several areas of constraints. Economic, time, environmental, social, political, ethical, health, and safety constraints.

4.2.1 Economic and Time Constraints

Since are group will not be sponsored by a company or an individual the group will have to use their own resources to buy all necessary parts and components to achieve the completion of the project in a timely manner. Aside from the financial economic constraint of the project. We have to pay attention to the cost to the deign the prototype because to make a device that is an affordable for all groups of people. If the prototype was to be to mass produced the group would like to make the price of the actual product range from $50 to $100. So, if the groups can achieve their goal of building the prototype with a budget of about $270 is should be feasible for the mass-produced final product to be within the aforementioned range.

The Time Constraint for the proposed system consist of the Spring and Summer semester of 2017, which is from beginning of Senior Design I to the end of Senior Design 2. To best meet these constraints the development will be broken up into two major components, research and then implementation. This can be seen in section 8.1, the milestones table goes into further detail about the structure of the two components for developing the proposed system and meeting the time constraints. Finally, the groups working and classes schedules which will be a factor in the project.

The research component will primarily take place in the Spring semester. This component will consist of researching different ways of developing the proposed system, as well as different competitors or related technology. The research portion should end once there is a good grasp of how the proposed system will be built, researching which parts need to be purchased, as well as, ordering those parts.

The second component for the development of the proposed system by the time constraints, is the implementation portion. During this phase, the Electrical Engineering students will focus primarily on building a physical prototype, while the Computer Engineering students will focus on programming the application and ensuring that the communication between components is functional.

The last time constraint for group will be their class schedules and working schedules. The two electrical engineers in the group will be taking another class along with senior design two. Depending on the work load of that course some time needed for senior design might be sacrificed to get the course work done. For the two computer engineers in the group their primary focus will be senior design two, because that is the only class they have to take in the summer to complete their degree. Another factor that will conflict the groups time is work. Every member of the group will be working around 25 to 40 hours a week at their internship. The time spent working will subtract from most time from the completing the project. As a result, this will potentially mean there is going to be a few last night working to complete the project on time.

4.2.2 Environmental, Social and Political constraints

When it comes to creating a product, the engineers need to have different constraints to consider. One of these constraints is the environment. The environment is an important constraint to consider since it’s the place in which every living human being lives, and it’s the responsibility for everyone to make sure that they do their part to make the environment as clean as possible for future generations to come. The Smart Light Hub is made so that it requires the least amount of materials needed to make sure that the footprint it leaves isn’t noticeable. For the sake of the environment the team decided of ditching battery’s and using the outlet as the power source of the Smart Light Hub. The reason being batteries have a horrible impact on the environment since they take many years to decay and release toxic chemicals which can harm wildlife and humans. While not a main goal, research will be made into renewable energy such as solar power to see if its obtainable to have a system powered 100 percent by free energy given from our sun.

The main goal of the Smart Light Hub is to illuminate a room with any color the user request with just a tap on a smartphone. To accomplish this the system needs to be in as many people’s hands as possible. The first goal is to make the Smart Light Hub system as affordable as possible. The price of a product has a great impact on a consumer’s choice of a product. Another way to reach more people is to allow to sell the product to as many places as possible. This makes it so people can see the product while also increasing the chances of people buying the product.

The next social constraint is how easy is it to set up and use the Smart Light Hub. The user should easily set up the product and be able to control the system through a smartphone. The computer engineers on the team made sure that the application which will run the Smart Light Hub is easy to use so that anyone of any age should be able to easily navigate and control the lights.

Furthermore, politics have a significant impact on how the country operates. This also affects how products are made since new rules and regulations are always coming out, which make companies change the way they manufacture goods. After conducting research on political constraints, it was found that none of them had a major impact on the Smart Light Hub.

4.2.3 Ethical, Health, and Safety constraints

The purpose of this product is to allow for the user to illuminate a room with the user of a smartphone. No corners will be cut on the system in any way to negatively affect the user. The Smart Light Hub will not use materials with are potentially toxic while also making sure the lifetime of the product last for years to come. Also, no features from the Smart Light Hub will be cut from the product to do finical reasons. The product which is being made will not break any patent protection and research will be done to make sure that credit will be given to the sources.

When designing the Smart Light Hub system safety is a great concern. Consumers who want to buy a product want to make sure that what they are getting is safe for them and their family. That’s why the Smart Light Hub will come with LEDs which will not cause any fires if a short circuit were to occur. Also, the system will be enclosed so that no electrical components will be in touch of the user. This will make it safe for the user to move the system from one location to another without damaging the internal components. It also means that when the user plugs the Smart Light Hub in the outlet that it will not electrocute the user. One benefit of having the system being operated by a smartphone is that once the system is turned on the user doesn’t have to interfere with or press any buttons on the system to change the lights. This makes the product last longer since there are less human interference and safer since if anything were to go wrong the user would be from a safe distance.

4.2.4 Manufacturability and Sustainability constraints

When designing the Smart Light Hub system, one manufacturing constraint to take into consideration is the availability of the materials. This is crucial since the team must take into consider how long each part has been in the market and how much longer it will be in the market before it is replaced with a newer part. Another part to consider is how many parts are available in the market. If there are thousands of parts available then getting a replacement wouldn’t be much of an issue, but if there are only a hand few left then getting the components could cause trouble and delay the development process or even change the component to something more readily available.

The sustainability goal of the Smart Light Hub system is to be able to have a life span of at least 5 years under normal operation conditions. The sustainability for this lie in the consideration of the environmental factor.

For the Smart Light Hub system to work, it must be able to withstand the different conditions which it might face. For example, the system must deal with different environmental conditions. It could be placed in an area which is over 100 degrees Fahrenheit such as Miami Florida and must deal with the rays of the scorching sun. It could also be used outside in the freezing cold such has Minnesota which can go 30 below freezing. The system should also be able to deal with shock which could come from dropping it to the ground. For these things to happen the Smart Light Hub will be made of durable plastic which will make sure that if the system were to drop from a high that the hub would not be seriously damaged. The system will also be in a housing which will protect the delicate electrical components from the outside elements. The system will also have a strong connection which will make sure that shock will not dislocate any components from the PCB or even worse damage it.

5.0 Design

After researching the different components for the Smart Hub Light system and weighing in the advantages and disadvantages of the different microcontroller and the Wi-Fi, the team can now design the actual software for the Smart Hub Light System, as well as develop the overall hardware of the Smart Hub Light System. Overall the components that were selected were best suited for the implementation of the Smart Hub Light System as well as the ease of implementing the software to the hardware components. The sections below contain:

- Hardware and software diagrams depicting the different pins of the microcontroller and Wi-Fi card, as well as, the overall communication between the microcontroller and the cellular device.

- Detailed explanation of the selected components that are being utilized for the Smart Hub Light System.

- Detailed Overview of the overall communication between the cellular device and the microcontroller and Wi-Fi card.

- Detailed Schematic of the different software aspects for the Smart Hub Light System.

5.1 Hardware Design

The hardware design of the Smart Light Hub consists of the microcontroller, wireless communication, lighting, power supply and the PCB which connects everything together. The hardware which we picked must comply with the specifications which was decided earlier.

5.1.1 Hardware Design Overview

In this section, the team will be presenting an overall overview of the hardware that is being utilized in the Smart Hub Light System. The purpose of the overview of the hardware components is to give the reader an idea of how the Smart Hub Light System is being built and developed.

DC voltage regulator

The voltage regulator is used to bring down the voltage from the DC power source so that the components connected to the microcontroller doesn't overheat and burn. The voltage regulator has a internal current limiting and thermal shut down and safe operation area protections making it a great chip for the project.

Part number: LM7805CT

Price per part: $5.38

Type: Surface Mount

Quantity available: 35,939

Looking at the components, the team was able to design the schematic for the DC Voltage regulator. This image can be found below and was completed using the Eagle CAD software.

Figure 30 - Schematic Diagram for Voltage Regulator

Crystal oscillator

The crystal oscillator is used to create an electrical signal with a precise frequency. The frequency will keep track of time and provide a stable clock signal for digital integrated circuit and to stabilize frequencies for radio transmitters and receivers. The crystal oscillator will keep the microcontroller stable.
Part Number: Uxcell a14050500ux0216 HC-49S DIP

Price per part: $1.04

Type: Surface Mount

Quantity available: 12,542

Looking at the components, the team was able to design the schematic for the crystal oscillator. This image can be found below and was completed using the Eagle CAD software.

Figure 31 - Schematic Diagram for Crystal Oscillator

Microcontroller

This microcontroller is a 32KB ISP flash memory with read while write capabilities. It has 32 general purpose working registers and serial programmable USART. With one clock cycle, it can achieve throughputs of around 1MIPS per MHz while also being able to balance processing speed and power consumption. This microcontroller is good for the project since it allows for it to be power efficient while also completing the task needed for the project.
Part Number: ATMEGA328P-PU

Price per part: $4.50

Type: Surface Mount

Quantity available: 10,752

Looking at the components, the team was able to design the schematic for the microcontroller. This image can be found below and was completed using the Eagle CAD software.

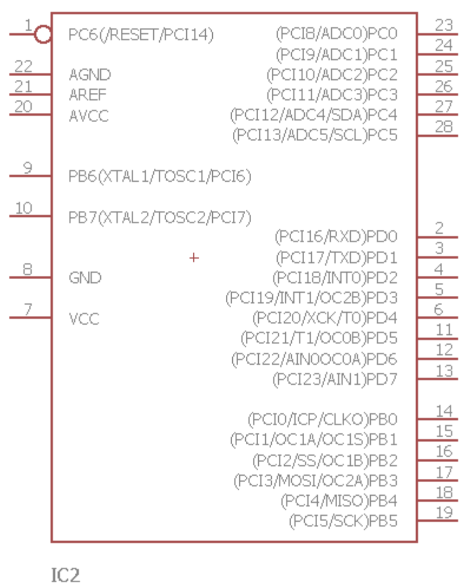


Figure 32 - Schematic Diagram for Microcontroller

Wireless Card

The wireless card is going to be used to send and receive data from the smart phone and send it to the microcontroller which will then decode and change the LEDs according to what the user requested. This wireless card is a smart choice for the project since its long range while also being power efficient. The small form factor of the card allows the team to make the smart light hub smaller and more compact.

Part Number: ESP8266

Price per part: $6.95

Type: Surface Mount

Quantity available: 95

Looking at the components, the team was able to design the schematic for the ESP8266 Wi-Fi module. This image can be found below and was completed using the Eagle CAD software.

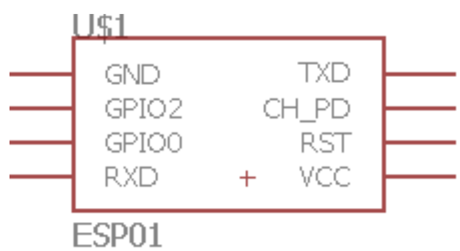


Figure 33 - Schematic Diagram for ESP8266 Wi-Fi module

RGB LED

The RGB LEDs which are going to be used for the smart light hub system will consist of 3 different light sources, one being red, green, and blue. With these lights, it allows for the user to pick any color they desire. The LED strips are great for this project since it allows the team to change the number of LEDs by cutting it. It also is small enough to carry and bright enough to illuminate a dark area.
Part Number: Adafruit NeoPixel Digital RGB LED Strip - White 30 LED

Price per part: $16.95

Type: Surface Mount

Quantity available: 1275

Looking at the components, the team was able to design the schematic for the RGB LEDs that are utilized in the Smart Hub Light System. This image can be found below and was completed using the Eagle CAD software.

Figure 34 - Schematic Design for the RGB LED

5.1.2.1 Microcontroller

The Arduino Uno microcontroller is the brain of the smart light hub system. The purpose of the microcontroller is to connect all the different components into one system. It also allows for the communication between the smartphone and the hardware components. The microcontroller will connect the RGB LED and wireless card together so that when the user asks to change the color of the LEDs it can send the information from the smart phone to the Wi-Fi card. The message will then be decoded and sent from the microcontroller to the RBG LEDs which will change color depending on what the user asks for. Microcontrollers have become very popular nowadays since they are relatively affordable and allow for engineers to basically create anything they desire since most electronic components are supported by the microcontroller. The microcontroller is an integral part for the Smart Hub light system because without it, there would be no communication of any kind between the cellular device and the hardware components.
The mains goals of the microcontroller include:

- Send and Receive data from the wireless card to perform different operations.
- Send signal to the RGB LED to modulate the color and patterns.
- Manage the power for the wireless card and LED lights.

The overall current being supplied from the microcontroller is only 20 milliamps. This is not bad, but in terms of trying to turn on the RGB LEDs, there is an issue because if you wire the RGB LEDs directly to the microcontroller, the LEDs will not turn on. The reason for this is because the amps that are required to turn on the RGB LED is 2 Amps. In terms of the overall Pin layout of a general ATmega168 microcontroller, this layout can be found in the figure below. The reason why this is important is because of the amount of hardware components that will be connected to the microcontroller. Another thing to note is that the Arduino Uno's microcontroller is actually called the ATmega168.

The Arduino Uno contains about thirteen Digital pins, five analog pins, and a ground and VCC voltage pin. Looking at the pin layout above, it can be seen that some of the digital pins represents different pins. For example, Pin 0 and Pin 1 of the ATmega168 are reserved specifically for modules that utilize any sort of data transfer that allows for communication of devices. These two pins are the pins that will be utilized by the Wi-Fi card. It will allow the team to verify that the communication between the phone and the microcontroller exists. In the next figure below, the team will analyze the overall schematic of the Arduino Uno and the reader will be able to see exactly how each port on the Arduino Uno operates. The reason why the team needs to include this figure is because the team wants to ensure that the person that is going to read the document will understand what each port does specifically, as well as, how each port on the Arduino Uno operates. The Arduino Uno is not one piece, but in actuality it is two pieces. The microcontroller itself is inserted into the Arduino Uno shield via an Integrated Circuit Socket. The reason why this diagram is important is because it shows exactly how the microcontroller is wired into the Arduino Uno Shield. The over schematic above shows exactly what electrical components are integrated into the connections of each of the pins that are found on the Arduino Uno. Overall in the above figure, it can be seen exactly where the diodes are inserted into the connections of the microcontroller and the Arduino Uno. The reason this is important is because those pins with the Diodes represent the Tx pin (transfer pin) and the Rx pin (Receiver pin). This becomes important in the case of this project because these two pins are the essentials for being able to communicate with the Wi-Fi module on the Arduino Uno Microcontroller.

5.1.2.2 LED

The smart light hub has RGB LEDs which mean they are LEDs which can change into whatever color the user desires. The LEDs are going to be powered by the microcontroller and controlled by the user which will select which color the LEDs should be. RGB means that each LED has 3 different lights one being red, green and blue. With these three assorted colors, it allows to create any color by manipulating how bright each LED is. In the figure below, the schematic will show the reader how the LEDs are going to be wired up for the Smart Hub Light System. While this is only a temporary design, as the project deadlines start approaching, the overall wiring of the LEDs will be changed until the team decides that the schematic for the LEDs is okay and easy for the programming of the different patterns of the LEDs. When wiring the LEDs for the Smart Hub Light System, a resistor must be implemented. The reason for this is because the voltage being supplied on the RGB LEDs is 5 Volts. The voltage being powered on the Arduino Uno is 12 Volts. Because there is a significant difference in the amount of voltage between these two, the resistor is included to ensure that there is no sharp change in the voltage drop across the RGB LEDs. If a sharp voltage drop occurs between the LED and the Arduino Uno, it can cause the LEDs to burn out which is not a good thing because while the team has a lot of LEDs ordered, having a RGB LED burn out because the electrical engineer forgot to include a resistor is really a waste on the Electrical engineer’s part.

5.1.2.3 Wireless Card

The wireless card is a critical component which will allow access to the device using wireless communications. With a wireless card, it allows for the smart light hub to be controlled by various remotes. This means it will be able to receive commands remotely

from the user and the wireless card acts are a decoder between the microcontroller and the user.
The main use of the wireless card includes:

- Receive data such as what color to change the LED, from the smartphone.
- Transmit data from the external device to the microcontroller through a UART interface to check for different information.
- Maintain compatibility with different devices.
  The table below shows the specifications of the wireless card selected for the smart light hub.

In the figure below, it can be seen that there are a few specifications for the ESP8266 Wi-Fi module. The reason why the specifications are listed below is because the team wants to see the overall required current and voltage that the ESP8266 Wi-Fi module requires. Also another thing to note in the diagram is that the specification table displays the overall frequency that is utilized at the input node of the ESP8266 as well as the input impedance and data rate. This is important because in the case when the team starts having multiple components, the overall voltage being supplied to the Wi-Fi module might be less than the required 3.3 Volts. This would be bad because then the team would have to redesign the entire Smart Hub Light System to make the Wi-Fi module operate efficiently. After looking at the overall schematic design for the Smart Hub Light System, the next step is to look into the overall Software design for the Smart Hub Light System. The reason as to why this is important is because the overall communication between all of the components for the Smart Hub Light System will need an application that takes control from the microcontroller to the ESP8266 Wi-Fi modules to the LEDs.

5.1.3 Schematic Design for Smart Hub Light System

After looking into the different components that were required to design the Smart Hub Light System, the team was able to develop a final schematic for the components that will be utilized in the overall Printed Circuit Board. A figure displaying the schematic design can be found in the figure below

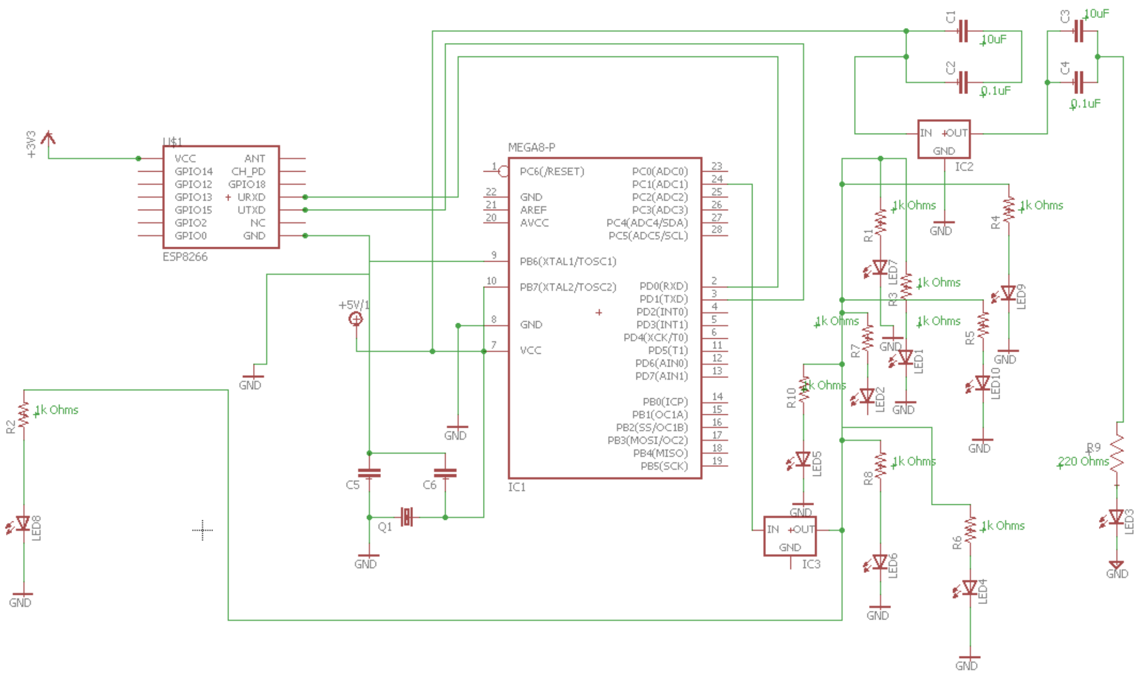


Figure 35 - Schematic Design for Smart Hub Light System

In the schematic above, there are multiple LEDs and resistors that are being utilized in the Smart Hub Light System. The reason as to why multiple LEDs are being used is because the overall goal of the Smart Hub Light System is to turn on different LEDs. These LEDs are going to be programmed in a way that they can be turned on by using a cellular device. The overall layout in the schematic diagram represents 10 LEDs which will be programmed to use 3 different patterns. The user will be able to utilize their cellular device which will give the user the option of selecting the pattern that they want. The microcontroller chip that will be utilized for the Smart Hub Light System is the ATMEGA328P. The reason why this chip was selected in the overall schematic design is because the team felt that from the research section, that this chip, which is utilized in the Arduino Uno, will be able to perform the basic needs of the Smart Hub Light System. The microcontroller chip allows the user to have almost 12 digital inputs and approximately 8 analog inputs. The reason why the number of inputs are important is because the number of components that are going to be connected to the Microcontroller includes a few voltage regulators, a few LEDs and a few resistors. Having these components all connected to the Arduino will be a challenge, but the team has been looking into options of utilizing multiple voltage regulators.

The voltage regulator allows the team to set a voltage output from the voltage that is coming from the microcontroller. The voltage regulator also allows the team to implement more than 10 LEDs which will be a plus in the design of the Smart Hub Light System. The reason as to why this is important is because with the implementation of different patterns, using only 10 LEDs means that there will not be a noticeable difference in the amount of LEDs that are going to be changed.

In the schematic diagram above, there is a block diagram of the ESP8266 Wi-Fi module. As it can be noted, not all of the pins in the schematic of the ESP8266 are connected. The reason for this is because for a device to connect to the ESP8266 from the microcontroller, only four of the pins need to be utilized. The four pins that will connect to the microcontroller are the TX pin, the RX pin, the ground pin and the voltage input pin. The main pains that allow for the data transfer pin and the receive pin because this allows the data that is being sent from the cellular device to transmit to the ESP8266 module. The data going from the ESP8266 module is then sent to the ATMEGA328 microcontroller. From the microcontroller, the data that is received on the microcontroller is then to the LED modules.

In the schematic above, there are a few capacitors and resistors that are utilized in the overall development of the Smart Hub Light System. The reason as to why the capacitors and resistors are included in the overall schematic diagram is because in order to have the LEDs turn on, there needs to be a resistor and a capacitor implemented. The resistor allows the voltage to remain the same while the capacitor holds the charge of the voltage which allows for the LEDs to not burn out. In all, the overall implementation of the resistors and capacitor is a good thing for the LEDs because it prevents them from burning out.

Looking at the final schematic above, it can be seen that both the voltages that are being supplied to the microcontroller and the ESP8266 are different. The reason for this is because in the data sheet for the ESP8266 Wi-Fi module is only capable of handling 3.3 Volts, whereas the microcontroller that is being used can occupy around 5.5 Volts.

Looking at the schematic above, there is a crystal oscillator being utilized. This represents the overall clock frequency that the microcontroller will be operating at. The reason why the team decided to display the clock frequency is because the team realized that this component for the Smart Hub Light System is very important. The crystal oscillator represents the overall processing speed that the microcontroller is capable of handling. The crystal oscillator is the main component that will ensure that the data is being transferred from the cellular device to the LEDs. The oscillators serves to ensure that the data packets are being delivered quickly and efficiently. In the final schematic above, it can be noted that there are two regulators, the regulators are the main components that will ensure that the voltage going into the microcontroller is the correct voltage that the Atmega328 microcontroller chip is rated for. The voltage regulator will also ensure that the ESP8266 Wi-Fi module has the correct voltage that the ESP8266 Wi-Fi module is rated at. Overall looking at the final schematic design for the Smart Hub Light System, the schematic is a rough final representation of the Smart Hub Light System. The schematic is subjected to change as the team starts developing the overall Smart Hub Light System. There are more components that will be implemented in the overall design of the Smart Hub Light System and the reason as to why the team has not shown it in the schematic diagram above is because the team is still working on gathering all minor components that will be needed for the Smart Hub Light System. All the major components have already been shown in the schematic above and the overall schematic is correct according to what has been tested in the Hardware testing section.

5.2 Software Design

Before any code is written, the software needs to plan extensively to maximize efficiency. In order to, achieve this, there are many different tools which can be used to plan out software. Unified Modeling Language (UML) is used in object oriented software engineering. UML Diagrams can be used to model the behavior, processes and the structure of an application or product. [43] There are many different diagrams which could be used, but for the proposed system, a flowchart, class diagram and use-case diagram were used.

5.2.1 Software Application Flowchart

A diagram used to display the functionality of an application or software is a flowchart. In a flowchart, the different symbols represent a different aspect of the system, for the legend for these symbols is located at the bottom left of the flowchart. For example, the cylinder represents an action taking place which involves the database. The arrows generally indicate the flow of data or the flow the user will go to.

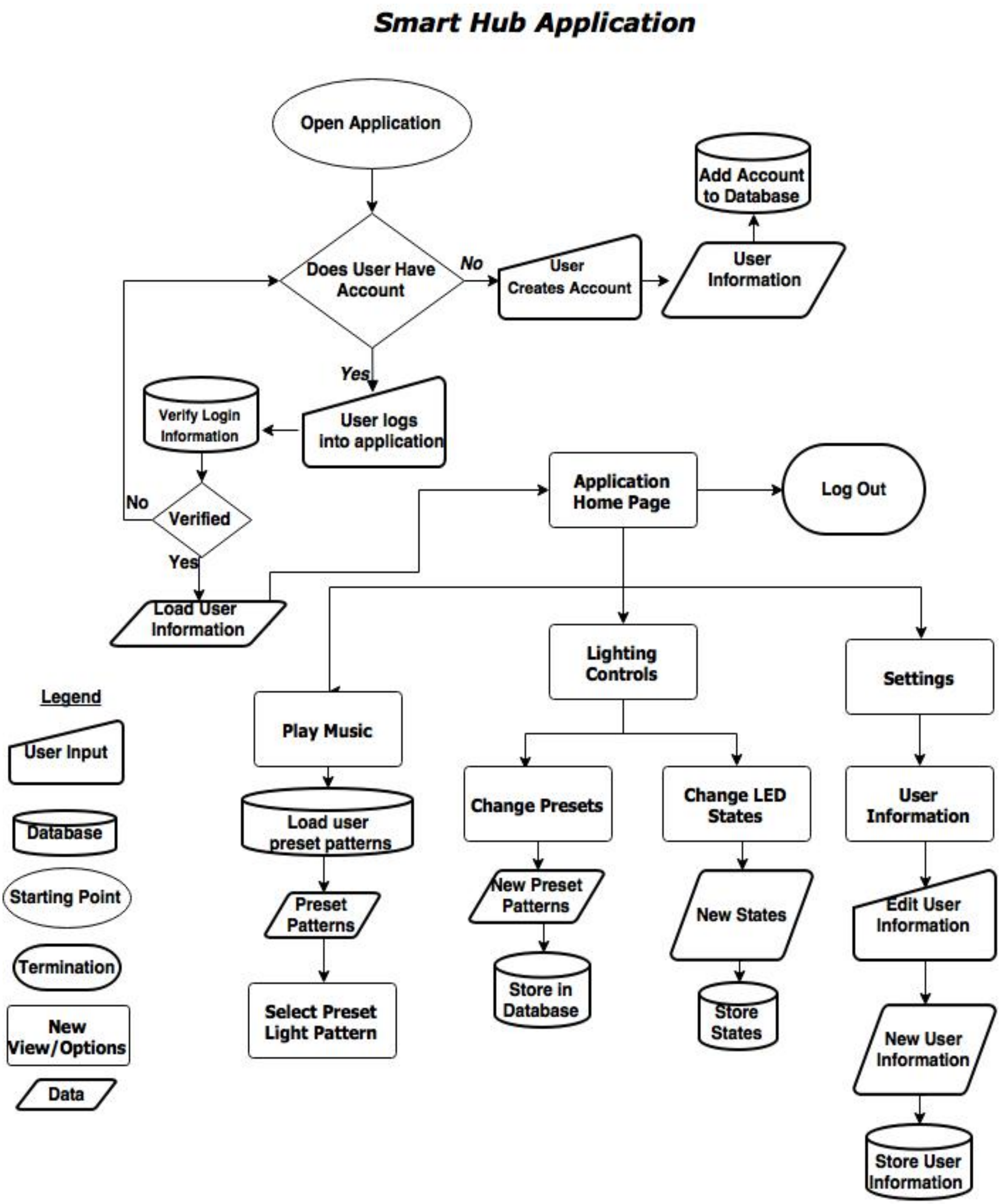


Figure 36 - Software Design Flowchart

is a representation of the capabilities and process the user will go through when using the application for the proposed system. The above uses various shapes and containers to represent different processes or actions which can take place, these processes are linked with arrows to show the flow the application will follow. For example, a cylinder represents access to the database, whether it be storing or receiving information.

Once a user enters this application for the first time they will have to create an account, the information manually entered by the user will then get stored in a Firebase Database. Now anytime the user enters the application they can log in with the credentials used to create the account, the Firebase database will then verify the credentials, if these credentials match what is in the database, the user will be taken to the home screen of the application. From the home screen a user can take 4 actions, play music, control lights, go to settings and log out.

The play music option allows the user to select music, from their device after the music is selected the database will load the preset LED patterns for that user, the user can then select one of these patterns to go along with the music.

If the user chooses to go to the lighting controls option on the home screen then they can choose to either change the preset patterns for the LED's or change the LED states. Changing the preset patterns of the LED's allow the user to select lighting patterns which will be used when the user chooses to play music. If the user changes any of their selected presets that information will be stored in the database. The other option the user has from the lighting controls is to change the states of the LED's, meaning turning them on or off and changing colors. Any changes to these LED's will be stored in the database so it will not be lost once the user exits the application.

The user can also choose to adjust the settings of their application, the main setting in this application would be the users personal account information. From this page, the user can edit all information such as name, email, username, and password. This data is then passed to the database to be stored. Firebase updates in real-time so the user will automatically be able to use their new account information.

The final option from home screen allows the user to log out of the application. This will then allow a new user to log in.

5.2.2 Use Case diagram

A Unified Modeling Language (UML) use-case-diagram is a diagram which shows the interactions between the system and its environment. The boundary of the system is represented by a large rectangular box. Actors, are represented by stick figures, these actors can be both systems or human. A use case is shown as an oval, this represents some functionality by a user or the system. If there is a line between a use case and actor that indicates that they are involved in this use case. The use case diagram does not show all the systems functionality, just models essential system behavior. The relationships can also be of type Include or Extends. Includes is a relationship points to a use case must be completed for the current use case to be completed. The purpose of this relationship is to remove behaviors which are common and repeated for multiple use cases. The extends relationship is used to mark optional functionality which is linked to a complete use case. [44]

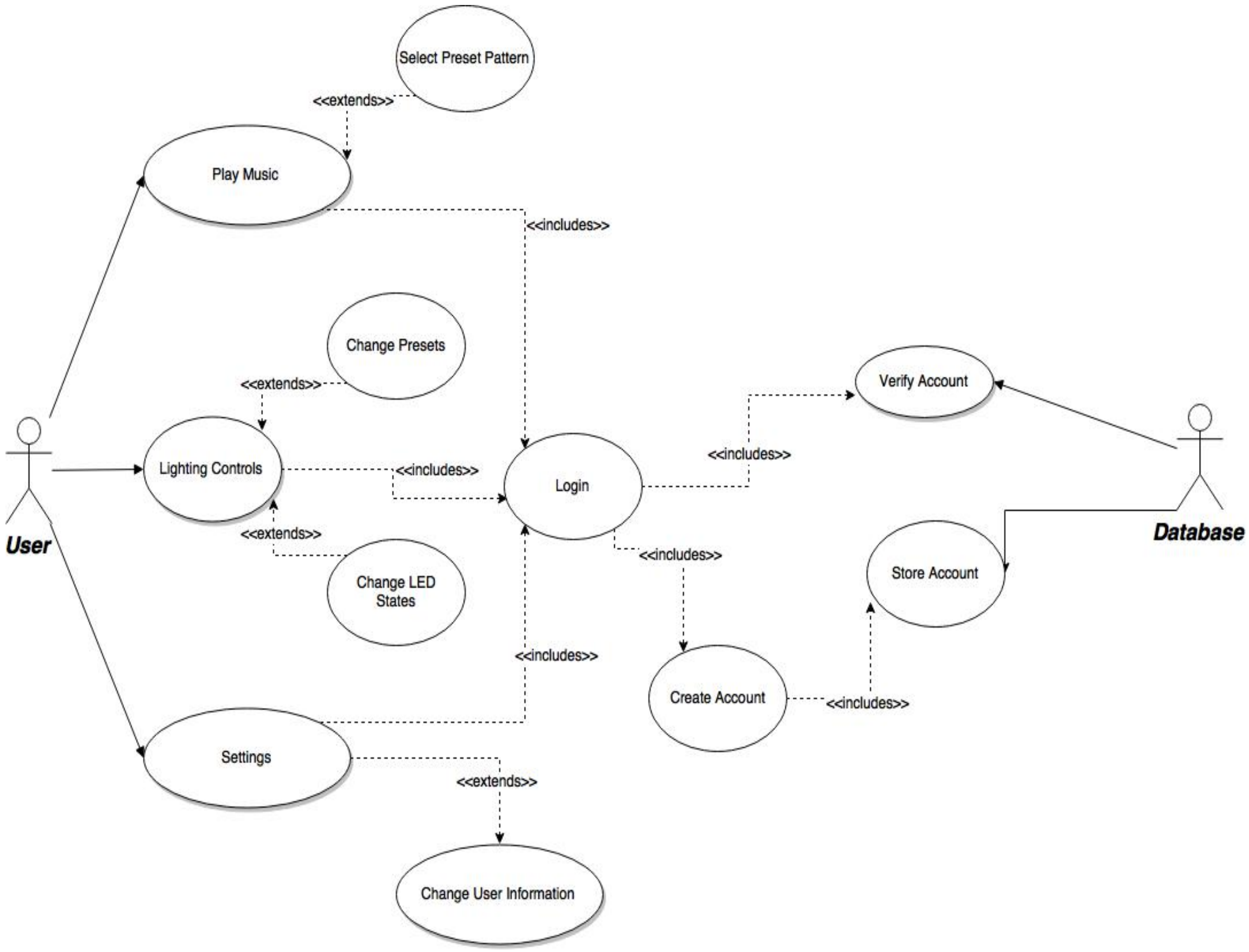


Figure 37 - Use Case Diagram

In Figure 37 the user has three main options, Play Music, Lighting controls, Settings, the extended behavior are some of the optional use cases available for those use cases. All the user main use cases include the Login use case, because for the user to have access to the main use cases of the application they must be logged in. Login includes create account and verify account because to login a user must first have an account, and then if the account exist the credentials must be verified before the user can have access to the application. **Error! Reference source not found.** diagram does not go into the details of the database use cases, but models the main functionality of the software.

5.2.3 Class Diagram

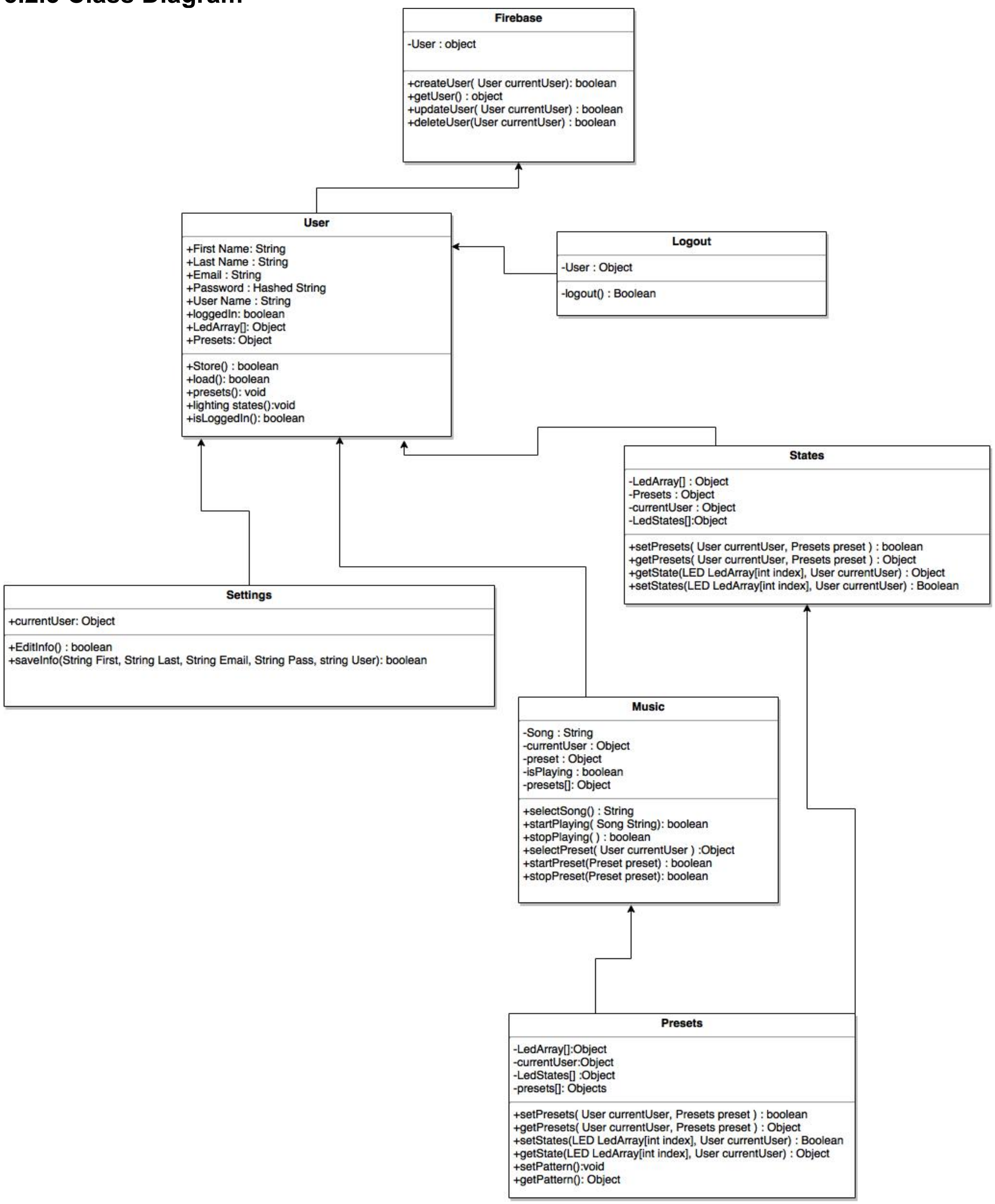


Figure 38 - Software Class Diagram

One of the most important models in UML documentation is the class diagram. This diagram is an entity relationship diagram which relates the classes in the system. Each class in the diagram is broken into three parts, the class name, Attributes and operations, from top to bottom. They show relationships between different classes such as association, dependency and generalization. [45]

Figure 38 show the class diagram for the proposed android application. There will be about 7 different classes, all associated to at least one other class.

Class Descriptions:
User

The largest class is the user class which stores all the user specific information. Almost every class in this system is associated to the user class. Each class is related to the user class since they each must access the instance of that specific user.

The *store*() method will be used to store the user's information into the database. This method will return a Boolean, indicating whether the information was added correctly.

The *load()* method loads the user's information from the database and returns a Boolean indicating if the information was loaded correctly.

The *presets*() method will allow the user to access their lighting presets.

The *lightingStates*() method will allow the user to update the states of the lights for their account.

The isLoggedIn() method returns a Boolean indicating whether the user is logged in, this will toggle whenever a user is logged out of the database.

Firebase
The Firebase class is used to store the user specific data, such as account information and any preset light settings.

The *createUser*(user) method will take in a new User as a parameter and add that user to the database. This method returns a Boolean indicating whether the user was successfully added to the database or not.

The *getUser*() method is used to get an instance of the user from the database. This method will return the reference to that user.

The *updateUser*(user) method will take in the current user as a parameter and update the elements in the database for that specific user.

The *deleteUser*(user) method will take in the current user as a parameter and delete the instance of that user from the database. This user will no longer have access to any of their information or be able to log into the application.

Logout
The logout class is small with one method, the *logout*() method is used to log the current user out of the application.

Presets

The Presets class is the main class controlling the preset light settings stored by each user. Classes such as States and Music inherit methods to control the states from this class.

The *setPresets*(user, preset) method takes in the current user and a preset setting, this method will then be pushed to the firebase database as one of the presets for the current user. This will return a Boolean indicating if the setting of the preset was successful.

getPresets(user) method will take as input the current user, and return the preset light settings which the user has saved in the database.
The *setPattern*() method is used to allow the user to create a lighting pattern to go along with music or just to display for a special effect.

The *getPattern*() allows the user to play the light pattern created with the *setPattern*() method. This method returns the light pattern.

The other methods for this class are from the States class, these methods are used to get and set the states of the lights, to ensure that the states do not change just because the user closed the application. More information on these methods can be found in the States class description.

States

The states class is used to set and get the states of the lights as well as have access to the preset light settings.

setStates(LEDArray, user) the set states method takes in the array of LED’s for the proposed system and the current user, and saves the states of those LED’s into the database, ensuring the states won’t change once the user leaves the application.

getStates(user) methods gets called to return the current states of the lights once the user reopens the application. For example, if another user was logged into the application this method would load the correct states for that user.

The methods regarding the presets are inherited from the Presets class and are used to allow the user to select a preset, start playing that preset and stop playing the preset. More information on these methods can be found in the Preset class description.

Settings

The Settings class primarily exist to allow the user to edit their account information and then save that information back into the firebase database.

The *editInfo*() method is used to make all the fields editable so the user can change the information in those fields. The Boolean returned will indicate if the fields are successfully made editable or not.

saveInfo(first, last, email, pass, user) method will take as input parameters the current user as well as their information. The main purpose of this method is to store the newly updated user information into the database. A Boolean indicating a successful push the database is returned.

Music

The Music class controls all method relating to playing and pausing the music as well as inheriting some methods from the presets.

The *selectSong*() method is called when the user would like to select a song from their list of music, this list will be implemented using some existing audio service. This method returns a string with the file name of the song to be played.

The *startPlaying*(songName) take the song name returned from the *selectSong*() method as a parameter, this methods main objective is to start playing the song. A Boolean representing whether the song began playing is returned.

The purpose of the *stopPlaying*() method is to stop the audio of the song playing, this method returns a Boolean regarding whether the song can successfully stop. For example, if the *startPlaying*() method has not be executed, then this method will return false.

The methods regarding the presets are inherited from the Presets class and are used to allow the user to select a preset, start playing that preset and stop playing the preset. More information on these methods can be found in the Preset class description.

6.0 Project Prototyping Construction

This will go into detail about prototyping of the Smart light hub. Prototyping is useful for any project. It provides many benefits for the developer and customers. Usually it's a small-scale version of the new design which can be shown to the customer to get initial feedback. Since most customers are not technical when they see the prototype it's possible to fine-tune the requirement for the project. It helps the developers by realizing problems with the design early in the project. This help to solve the those realized problems quickly. it also helps to realize how expensive the project could be to get more financial support.

6.1 Software Prototype

The software prototyping consisted of building the application and designing a functional user interface. The user interface is an important aspect of software design, if the user interface is not functional there is a chance of the user not being able to navigate through the application properly. The user might not be able to find a feature, and not get the full functionality of the application. Designing the interface in a functional way which allows for good learnability and memorability will ensure users continue using the application. Shown below is the flow a user will go through when using this application, from creating an account, to selecting music.

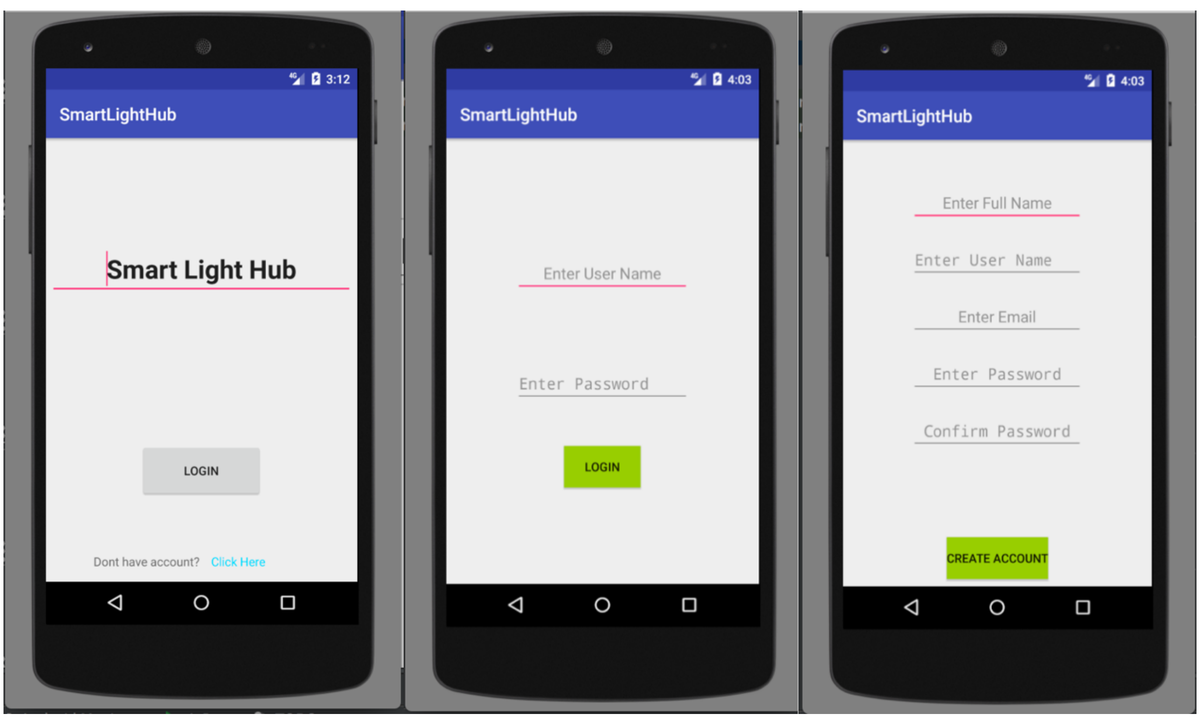


Figure 39: Starting Screen, Login Screen and Create an account

Figure 39 shows the starting screen of the application allow the user to either press the "Login" button to login to the application with their account store on the Firebase database, or the "Click Here" button to create a new account and store the new user information in the Firebase database. These screens can be seen above in Figure 39

From the Account Creation screen the user will enter their Full Name, User Name, Email Address, their password must be entered twice to confirm it is correct. After the account is created they will be send an email, verifying that they created an account. The user will then be able to re-open the application and go to the login screen.

From the login screen the user can enter the credentials used to create their account, being their user name and password. Once they hit the login button, Firebase will verify that the credentials match, an entry in the database. If the credentials are verified the user will be taken to Figure 40 the Home screen of the application.

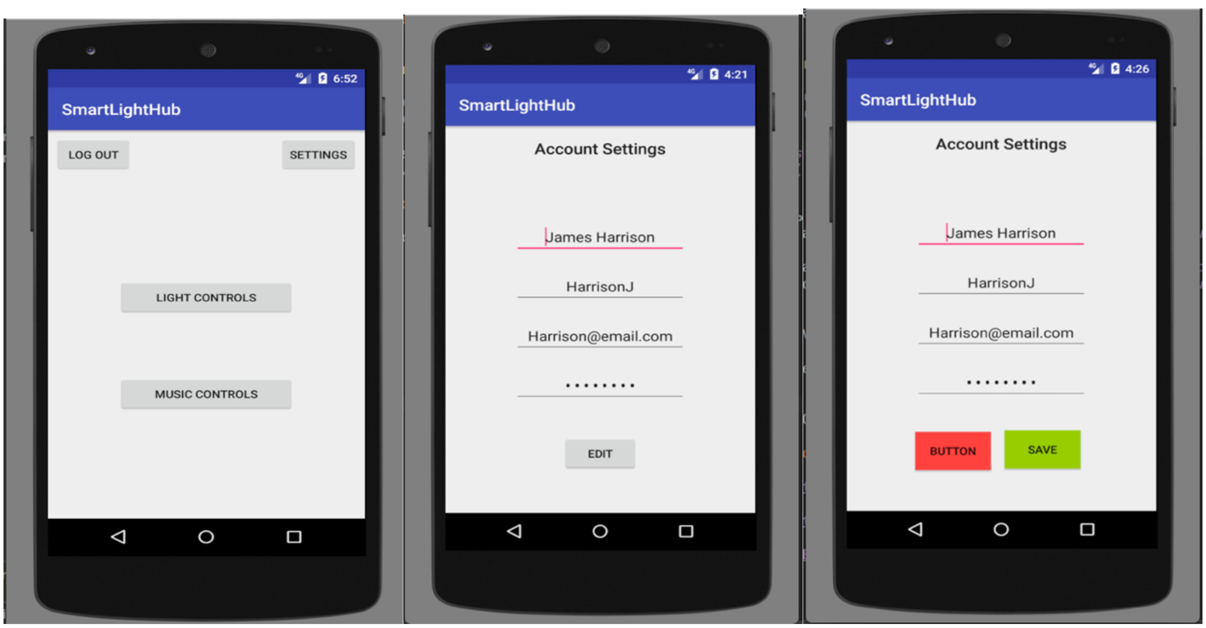


Figure 40 - Home Screen and Settings Page

From this screen, the user has multiple options, they can navigate to the lighting or music controls, settings or they can log out of the application completely. If the user presses the log out button they will be returned to Figure 39 and another user will be able to access the application. The states of the lights from the previous user will be left unchanged, until a user, changes them. For example, if User 1 left the lights on, User 2 can log in and turn them off, or User 1 can log back into the application and turn them off, but they will not turn off automatically once the user exits the application.

If the user presses the settings button, they will be taken to the second image in Figure 40 which shows the settings page, as well as, the multiple states in which the page can exist. The main purpose of the settings page is to allow the user to edit their personal information for their account. The image on the left shows the initial state of this page, once the user presses the edit button, the fields will become editable and change to the image on the right, the third image in Figure 40. Allowing the user to change their personal information and then save it into the database.

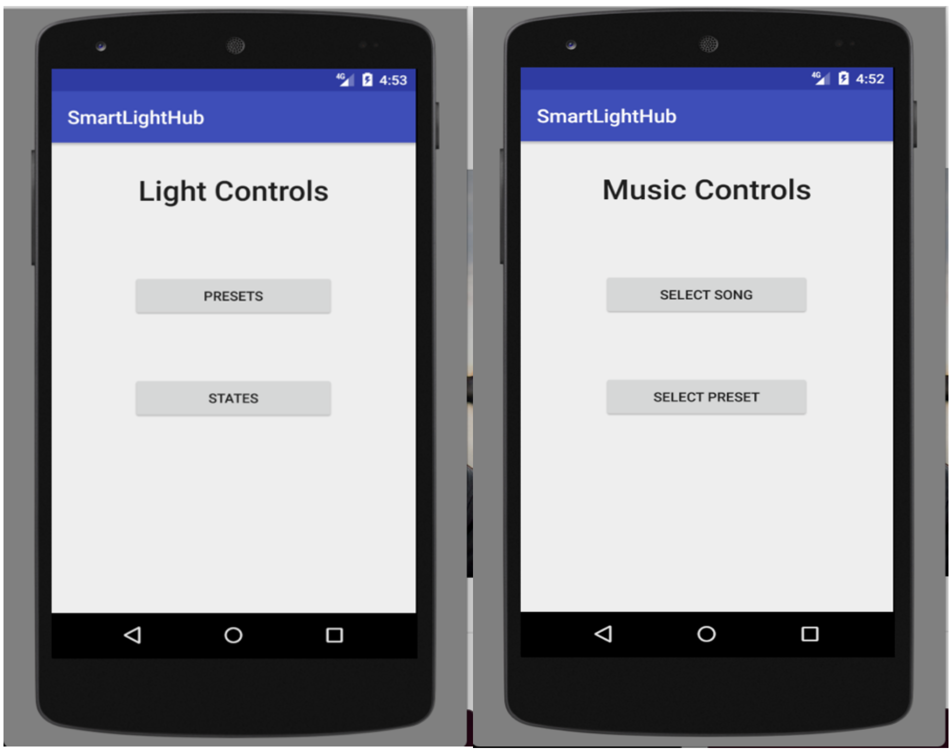


Figure 41 - Light and Music Controls

From Figure 40 if the user presses the Light Controls button, they will be taken to Figure 41 which is the Light Controls screen. From this screen, the user can navigate to a view to create or edit their preset light settings. Also, they can navigate to the states view, where they can change the states of their lights, for example, changing the colors, or turning them on/off.

From Figure 40 if the user presses the Music Controls button, they will be taken to Figure 41 which is the Music Controls Screen. From this screen, the user can select a song, either from preset songs or from their library. In addition to selecting the song the user can select the preset light setting to play along with the selected song.

6.2 Hardware Prototype

In this section, the hardware for the Smart Hub Light System will be developed here. There will be images showing the actual components that was utilized during the Breadboard Testing as well as an overall image of the components that were ordered. The fist image that will be shown in the figure below is the layout of the different components that were ordered for the Smart Hub Light System.

So in Figure 35, it can be seen that the Microcontroller can be found in the right part of the image. The ESP8266 Wi-Fi module can be found in the bottom left of the image and in the three bags shown above. The wires to the far left are breadboard wires that were utilized in the overall Breadboard Testing for the Smart Hub Light System. There are also a few Female to male header wires that were utilized during breadboard testing because when wiring the ESP8266 to the Arduino Uno module, there was no physical way to implement the ESP8266 on the breadboard without using these wires because if it was implemented on the breadboard directly, it would have shorted out and blown the entire microcontroller and Wi-Fi module. Also in the figure above, the microcontroller shown is not the only one, it was just because when the breadboard testing occurred at the time, there was only one Microcontroller. As of right now, the team has more than one microcontroller in the event that the microcontroller burns out. The next thing that can be noticed in the image above is the clear, circular tube of wire. Inside the clear circular tube of wire is the actual RGB LEDs for the Smart Hub Light System. Now for the purpose of breadboard testing, the RGB LEDs were cut at marked locations on the strip. Those marked locations were the breaking point where the LEDs could be cut without interrupting the actual circuit connection of the RGB LEDs. Once the RGB LEDs were cut, the next step for the RGB LEDs is to solder on wires that represent the positive 5 Volts connection, the Data Input connection and the ground connection. The next step after the wires are soldered is to ensure that the connections are fully attached to the RGB LEDs. Once it is attached, you take a female to male wire and connect it to the 5 Volts on the Arduino Uno. Then you take another female to male wire and connect it to the ground portion of the Arduino. After that, you take the Data Input Pin and connect it to Pin 2 on the Arduino Uno. The reason why the Data Input pin on the RGB LED is connected to Pin 2 on the Arduino Uno is because in the documentation online, when the LEDs are wired, usually the default pin that is used to turn the RGB LED on is the Digital Pin 2 on the Arduino Uno. A figure displaying the actual test of the Smart House Light System can be found below. Overall the design displayed below is a rough test that was performed for the microcontroller and for the ESP8266 Wi-Fi modules. There are still more components that will be included in the overall design of the Smart Hub Light System. However the test that was performed on the breadboard below is for the major electrical components that will be utilized in the development of the Smart Hub Light System. The LED being used in the Smart Hub Light System below represents that the microcontroller is functioning fully and that there are no errors in the overall wiring of the circuit shown on the breadboard.

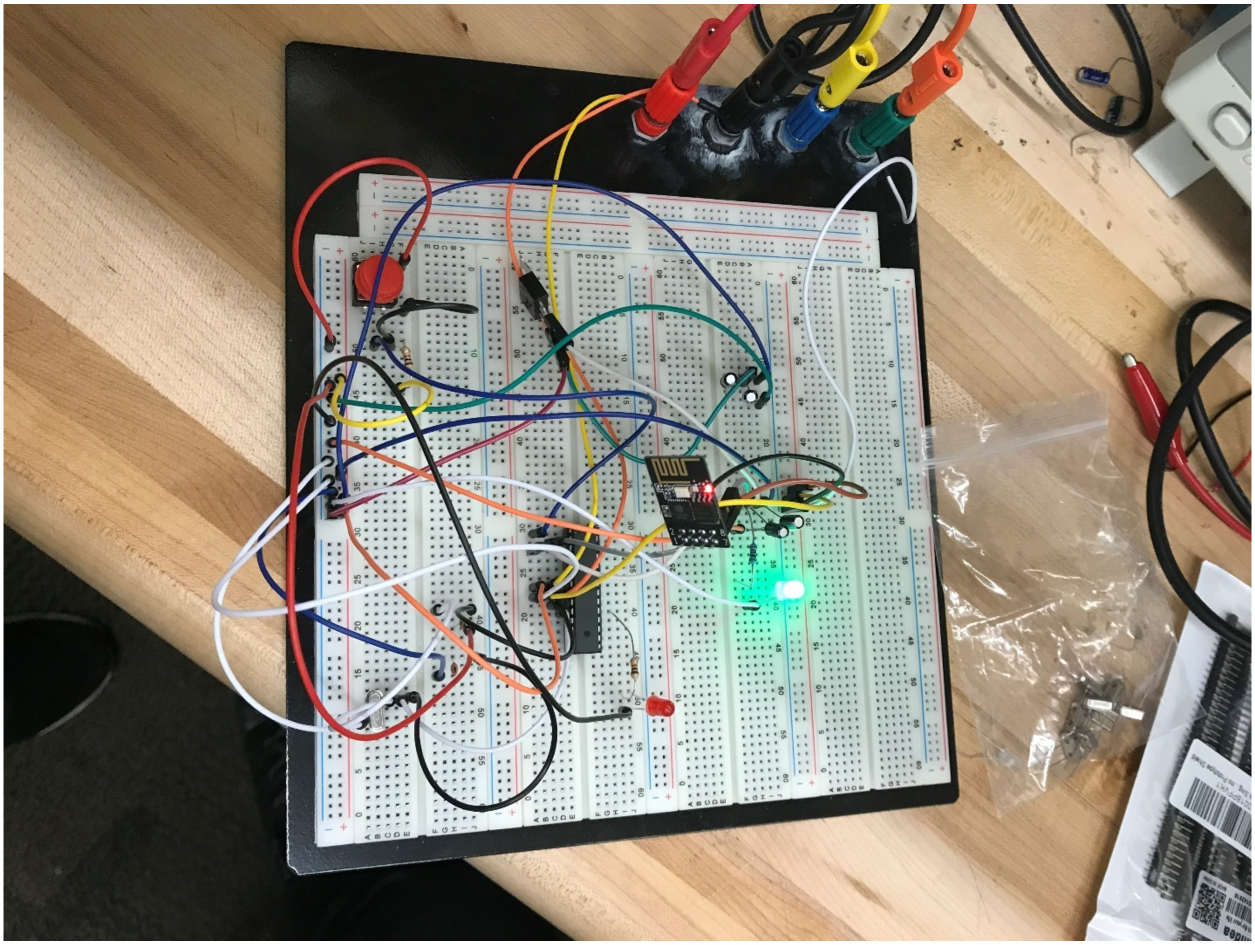


Figure 42 - Breadboard Prototype Testing of Components for Smart Hub Light System

Looking at the figure above, it can be seen that the four connectors on the breadboard is connected to the actual DC Power Supply that was found in the lab. Overall, when hooking up the Arduino Uno to the DC Power Supply, the team encountered an error where the pins on the Arduino Uno were not labeled as clearly. Because of this, the first time the team tried to turn on the Arduino Uno Microcontroller, there was a mismatch in the location of where the Ground pin was and the Voltage Input Pin. Because of this, the first time the team hooked up the LED, they noticed that nothing was lighting on and on the DC Power Supply, it was showing that there was an overload occurring. So what the team did immediately was reverse the Voltage Input pin and the Ground Pin. On the DC power supply, the team set the voltage to 12 Volts. The reason why this is important is because if the team supplies a voltage that is less than 12 Volts, the Arduino Uno will not turn on at all. If the team supplies a voltage that is over 12 Volts, then the Arduino Uno will burn out completely. So once the team was able to turn on the Arduino Uno, the next step was to wire the ESP8266 Wi-Fi module. To wire the ESP8266 module, the team utilized the documentation sheet that is provided online. One case with this module is that if you overload the module with a voltage of 5 Volts. The entire module is completely fried and becomes useless to the team. So because these modules burn out easily, the team was really careful when wiring the pins of the ESP8266 module to the Arduino Uno. The team used the Tx pin (Pin 0 on Arduino Uno) and Rx pin (Pin 1 on the Arduino Uno). Once those connections are made, the next connection that is necessary is the Voltage input. The ESP8266 can only handle a maximum voltage of 3.3 Volts. Luckily on the Arduino Uno, there is a voltage regulator that contains a pin that has 3.3 Volts. So once the ESP8266 is wired correctly, the next step is to verify that the LED is lighting on the ESP8266. If the LED is lighting red on the ESP8266 module, then the module is connected correctly. If no LED light is displaying on the module, then either the connection that is made is incorrect or the ESP8266 module itself has burned out. To verify if the module is burned out, take a digital multimeter and measure the voltage going across the module. If the voltage displayed is near zero then that means the ESP8266 is fried. Once that is completed the last step for the breadboard testing was to wire up the RGB LED to the Arduino Uno. For the team's case, when wiring up the LED, the team noticed that there was no light being displayed. When the team measured the voltage going across the LED, they were getting a reading that matched the set amount of voltage on the DC power supply. After reconnecting the wires and rebuilding the circuit, there was still no display of the LEDs. Upon further inspection of the documentation, the amount of amps that are needed to turn on the LEDs is 2.0 Amps. The problem with this is that in the lab, the maximum amount of amps that the DC power supply can handle is 0.5 Amps. This is a huge issue because if there is not enough current going through the LED, then the LED will just not turn on completely. The voltage will pass through it, but the current is what is the main key when trying to get the RGB LEDs to turn on. So what the team realized now from when they performed the initial test is that they are going to require a power supply. Luckily, the team has already ordered a power supply and will be continuously testing the RGB LEDs until they are functioning correctly. So overall, the prototype testing of the Smart Hub Light system was a success because most of the major components of the Smart Hub Light System are functioning correctly. In the schematic above, the microcontroller can be seen as the main component in the breadboard above.

6.3 Light Enclosure Design

The LED's for our project needs to represent a light bulb. Since we are targeting the market automated lighting system. A three model of the enclosure was designed to give the read a better idea how what we are trying to accomplish with the project when building the lights that will be controlled but are hub system. in the figure below it can be seen that the sketch of the light enclosure was draw up. After the initial phase, it was later modeled to for the propose of being printed by a 3d printer. Since these drawing are the concepts it is possible for changes to made. Also, the concept model does not take into account he dimensions of the LED's and PCB. They will have to add later by the tools used to 3d print.

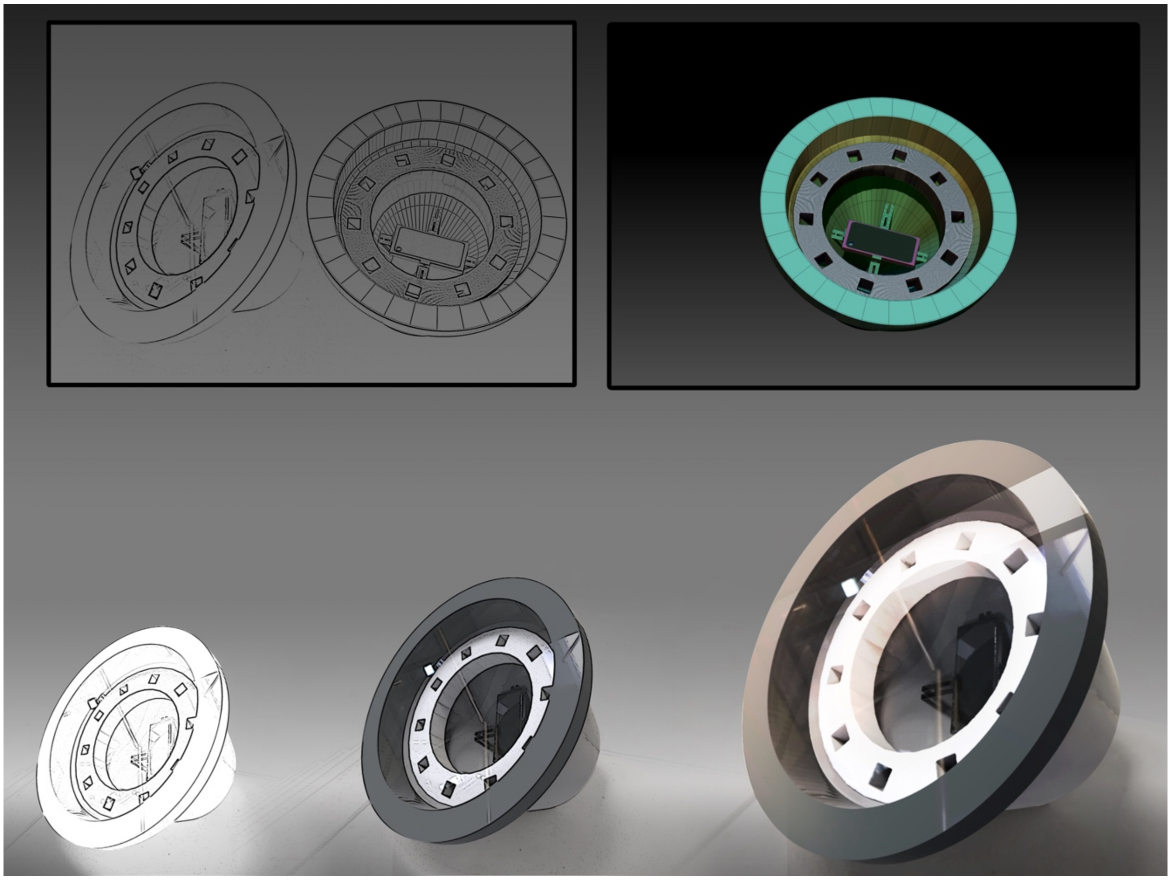


Figure 43A - LED Light Enclosure

In the figure below is can be seen that how the LED's will be placed in the system and how the PCB will be installed in the system. From the LEDs there will be three wires going to the PCB a red green and black. Red wire will supply the lights the necessary 5v input, the black wire will ground the LED's and finally the green wire will supply the LED's with digital modulated single so the light will change according how the program defines it. From the PCB there will two wire that will exist the enclosure. There will be two wires a black and red wire, the red wire will supply the system with correct voltage and the black will ground the entire system. The LED's will sit where square cut outs are and all of those wiring will be hidden. The PCB will sit in the back where the bracket system was design to do so. this entire enclosure will be printed using the 3d printing service provide to us by UCF.

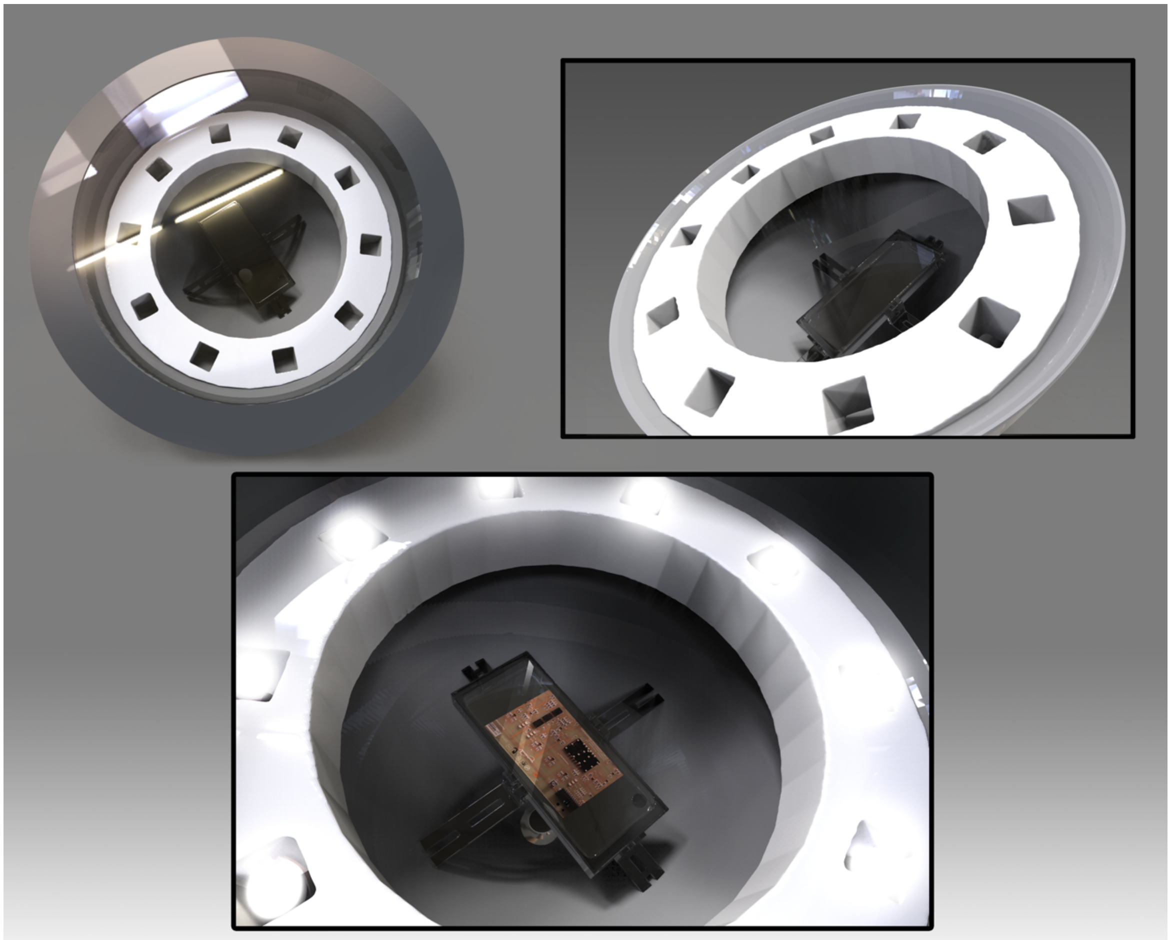


Figure 43B - LED light Enclosure

7.0 Testing Plan

This section will go into extensive detail about testing the parts of the smart light hub. The purpose of having a testing plan it to make sure that every core aspect of the project is working correctly. This will consist of hardware testing and software testing. Testing is integral part when design as system with multiple subsystems. Testing helping to protect again avoidable large system failure.

7.1 Software Testing

Before software is deployed extensive testing should take place. Ensuring not only that the software can complete the necessary objectives, but also to ensure that any fatal errors are not found in the software. The proposed Android application will need to allow users to login, the content each user can access will be loaded from the database, the application should then be send a signal to the smart hub to change the states of the LED's. There are many errors which could occur in this process, such as the states of the lights not updating, so the objective of this testing is to find these errors such that the application can function completely.

The testing was broken down into two main portions, testing just the application functionality, this can be done during development and then testing the communication between the software application and the hardware smart hub.

7.1.1 Application Testing

The testing of the application test consisted of ensuring that a user could create an account, login, and ensuring that the content such as LED states a user changes are stored and loaded from the database. This testing can take place on a physical Android device or and emulated device.

7.1.1.1 Register new account

This application will support multiple users, allowing data specific to each user. To use this application and allow user specific data each user must register for a new password protected account. This account and data will be stored in a Firebase database.

Procedure: Steps taken to test the account registration.

1. Open the application, and click “Register for Account".

2. The user must enter their Name, E-mail Address, and a password.
3. After the necessary information is entered, click “Register”, a verification E-mail will be sent to the email entered.
4. Once the user verifies their account they have successfully created an account, and can login to the account.

7.1.1.2 Login

To use the application, the user must use the account previously registered for to login, this will allow the user access to their specific data.

Procedure: Steps for testing account login

1. Once the user has registered and verified their account. They must click the “Login” button.
2. The user must enter the correct E-mail address and password.
3. If the credentials do not match the database entry, the application will not advance and the user will be prompted with a message “Either Email or Password are incorrect”. If the credentials match the database, the user will be granted access to their specific content and be directed to the homepage of the application.

7.1.1.3 **Saved States**

This application will need to save the user specific data in the database such that once the user logs into the application, the data is loaded from the database, and is stored when changes occur, so the user can safely exit the application.

Procedure: Steps for testing if the user specific data saved properly, there are several aspects of the application to be tested at this portion, such as the preset light settings and the

1. Login to the application, the first portion to be tested will be the states of the LED’s, so navigate to the lighting controls, and change the states, for example if they were on turn them off.
2. Exit and reopen the application, navigate to the same lighting control options and ensure that the states are the same as right before the exit of the application. If the states are different, the database is not storing the changes.
3. Next the music presets will be tested, navigate to the music options, choose a song and select a preset lighting pattern, this pattern should show a message “Pattern Playing”.

4. Exit and relaunch the application to ensure that the selected pattern is still in the correct state. If the pattern is not in the correct state there is an issue pushing the state to the database.
5. Finally, navigate to the settings, once in the settings modify the user information, the name, email, password initially stored when the user created the account.
6. Relaunch the application and attempt to login with the new credentials, if the credentials did not update in the database the “Either Email or Password are incorrect”. Message will be shown. If login is successful, the database successfully stored the new credentials. Navigate to the settings and user information, and verify the information saved.

7.1.2 Communication Testing

The Android application is the main control source of the proposed smart hub light system. This application will send a signal based off the user’s selection to the smart hub, the hub will then control the states of the lights. The objective of testing this portion of the system is to ensure that the signal reaches the LED’s correctly. Also, to ensure the states of the LED’s do not change once the user exits the application.

Procedure: Steps taken to test the communication between the application, smart hub and LED’s. These steps will be like the saved states application testing.

1. Login to the application, navigate to the lighting controls, and change the states of the LED’s. The smart hub system should automatically change the state of the LED. If the LED did not change, there is an error.
2. Relaunch the application and ensure that the LED didn’t not change while the application was closed.
3. Navigate to the music options, choose a song and select a preset lighting pattern, this pattern should show a message “Pattern Playing”. The smart hub system should change the states of the LED’s to model the pattern selected. If the states have not changed there is an error with the communication.
4. Relaunch the application and ensure the preset pattern did not stop as the application was closed.

7.2 Hardware Testing

Hardware testing is vital to any project or invention. It allows for the engineer to see what parts are suitable for the device. It also important because it allows the engineer to make sure that every component is working correctly before connecting all the component together.

7.2.1 Microcontroller Testing

The microcontroller is the brain of the smart light hub project and needs to be tested to make sure that all the pins and connections are working correctly to allow for the project to work without a hitch.

Procedure: Steps needed to test the Microcontroller

1. Attach power source from the outlet to the power-in for the microcontroller.
2. Check the LED light on the microcontroller to check if its powered on.
3. Press the reset button on the microcontroller and check to see an orange light which indicates the code being reset.
4. Attach a LED light to the correct pins and check if it turns on.
5. If it turns on then try it on the other pins to make sure that all the pins are operational.

7.2.2 LED Testing

The LED is the light source for the smart light hub project. It must be able to turn on and off while also being able to change color depending on what the user requested on their smart phone.

Procedure: steps needed to test LED lights.

1. Connect LED light to microcontroller by connecting it to the correct pins.
2. Attach a power source from the outlet to the microcontroller which will power up the microcontroller and have enough power to turn on the LED.
3. Check the amount of voltage and current which is being given to the LED to make sure it’s not getting burnt.
4. Have a preprogramed code which will change the color of the LED light to every color to make sure that it works correctly.
5. Run the code in the microcontroller and check the LED to see if it can produce every color.
6. Press the reset button on the microcontroller and check if the LED turns off.

7.2.3 Wireless Card Testing

The wireless card is going to be how the user interacts with the LEDs from a smartphone. The wireless card will be connected to the microcontroller which will then change the color of the LED.

Procedure: Steps needed to test the Wireless Card

Attach the wireless card to the correct pins in the microcontroller.

Attach the power cord to the microcontroller which will power on the microcontroller and the LED light and the wireless card.

Check the amount of voltage and current which is given to the wireless card to ensure that its working correctly.

User selects what color the LED should be on the smartphone and sends the signal to the wireless card.

The color of the LED should change if it does it means that the wireless card is working correctly.

Press reset button on the microcontroller and try it again to make sure it can happen again.

8.0 Administrative Content

This section of the paper encompasses how management of the project was done. All the engineers will have to deal with managing project later in their career and this portion shows how well equipped they are to progress into the field as growing engineers. The project was managed by meeting the deadline associated with milestones, the group also had to manage the project by working hard to adhere to the proposed budget, and finally they prepare closing remarks of the paper which deals with the overall project.

8.1 Milestones

Our project milestones were broken into two major section senior design one and senior design two. With senior design one consisting primarily of doing research of the major component of the project. Also, with senior design two consisting of integrating all the parts of the project to create the system described throughout this paper. Developing milestones for any project is critical because it gives everyone some tangible deadlines to meet to keep everyone on track. These estimated deadline dates helped prevent the group from falling be hide.

Table 10 - Senior Design One Milestones

Senior Design 1 Hardware Section					
Number	Task	Start	End	Status	Responsible
1	**Ideas**	**1/23/2017**	**1/26/2017**	**Completed**	**Group 2**
2	**Project Selection & Role Assignment**	**1/28/2017**	**2/27/2017**	**Completed**	**Group 2**
Project Report					
3	Initial Document- Divide and Conquer	**1/31/2017**	**2/3/2017**	**Completed**	**Group 2**
5	First Draft	**2/6/2017**	**3/31/2017**	**Completed**	**Group 2**
Research, Documentation & Design					
6	Initial PCB Stage	**2/6/2017**	**2/24/2017**	**Completed**	**Ryad**
7	Mobile OS & IDE	**2/6/2017**	**2/12/2017**	**Completed**	**James**
8	Open Source API's	**2/6/2017**	**2/12/2017**	**Completed**	**Anthony**
9	LEDs	**2/14/2017**	**2/19/2017**	**Completed**	**Kevin**
10	Database	**2/14/2017**	**2/20/2017**	**Completed**	**Anthony**
11	Open Standard Protocol	**2/14/2017**	**2/20/2017**	**Completed**	**James**
12	Wireless Technology	**2/22/2017**	**3/9/2017**	**Completed**	**Kevin & Ryad**
13	Microcontroller	**2/22/2017**	**3/9/2017**	**Completed**	**Ryad**
14	Design Login Process	**2/22/2017**	**3/9/2017**	**Completed**	**Anthony**

15	Login Backend Implementation	**2/24/2017**	**3/9/2017**	**Completed**	**James**
16	Power Supply	**2/14/2017**	**3/6/2017**	**Completed**	**Kevin**
17	DDR RAM	**2/18/2017**	**3/2/2017**	**Completed**	**Ryad**
18	Portability	**3/3/2017**	**3/16/2017**	**Completed**	**Kevin**
19	Form Factor	**3/3/2017**	**3/16/2017**	**Completed**	**Ryad**
20	Material Composition	**3/6/2017**	**3/21/2017**	**Completed**	**Kevin & Ryad**
	Packaging	**3/6/2017**	**3/24/2017**	**Completed**	**Kevin & Ryad**

Table 11 - Senior Design Two Milestones

Senior Design 2					
Number	**Task**	**Start**	**End**	**Status**	**Responsible**
22	**Build Prototype**	**3/6/2017**	**5/2/2017**		**Group 2**
23	**Testing & Redesign**	TBA	TBA		**Group 2**
24	**Finalize Prototype**	TBA	TBA		**Group 2**
25	**Peer Presentation**	TBA	TBA		**Group 2**
26	**Final Report**	TBA	TBA		**Group 2**
27	**Final Presentation**	TBA	TBA		**Group 2**

8.2 Budget and Finance

Since our project will be not sponsored by a company the group has deiced to create to budgets the first being the maximum allotted which is $750 but since we would like this product to be cheap for the user we decided to put an internal cap on the budget which is $250. Although this amount also seems to be a little pricey this is the prototyping cost which should be significantly higher than the actual cost. if this product was to be mass produced we would see considerable drop in price which make it more affordable to all group of people of different social classes. The cost of all major components are listed in the Figure 12 below.

Table 12 - Project Cost

Description	Vendor	Price Per Unit	Amount	Total Estimated Price
Microcontroller	Arduino	$24.99	1	$24.99

RGB LED	Adafruit	$29.99	1	$29.99
Soldering Iron	Vastar	$16.99	1	$16.99
Foxnovo Breadboard Jumper Wires	Foxnovo	$4.99	1	$4.99
Breadboard	RioRand	$27.95	1	$27.95
ESP8266 Wi-Fi Module	MakerFire	$3.99	4	$15.99
Breadboard Jumper Wires	Z&T	$7.29	1	$7.29
ATmega328P MicroChip	Arduino	$4.50	3	$13.49
16 MHz Clock Oscillator	Quartz	$1.05	10	$10.50
LM7805CT Linear Voltage Regulator	DataAlchemy	$5.38	2	$10.76
22pF Capacitors	Amazon	$0.10	50	$5.63
Capacitor Kit	LtvyStore	$0.06	200	$11.99
Component Pack with Resistors and Switches	Elegoo Electronics	$0.04	200	$7.96

9.0 Conclusion

The group has spent has many hours doing intensive research to provide an optimal design for the Smart Light Hub. For the hardware, the electrical engineers looked at various microcontrollers, Wi-Fi modules, and similar technology to compare the nature of the different components to find a component that would help us design are intended product. As for software, the computer engineers considered many software development environments, mobile platforms and databases to give the user the best experience using are product. The product we designed can compete with the major market. We have provided many new feature that have not been seen by related products. As the market for smart home device and the internet of things continues to expand we could see this being implemented in standard homes designs. The main reason the group deicide to work on a project like this was are passion for technology and wanting to eliminate mundane tasks to make life simpler for the people. Being inspired by many emerging smart home devices. The group set out to make a smart home lighting system which is compact, low cost and energy efficient smart light hub with a free mobile application associated with it.

The group did research in various technology's in section three documents all the selected components and software need to make this project possible. We have selected are indented microcontroller and the chipsets. Also, selecting a Wi-Fi module to let us communicate to the various parts of the system. the LED selection was done because its large support from the community and manufacture. also, we discussed why we choose to develop are mobile application using android and the database that will be used to store important user information while keeping it secure. How we are going gain access to music for the application without limiting are user to a define selection, by using the Spotify SDK. We looked at different ways to manage the workload of the project by using numerous management tools such as slack, trello, Git, GitHub, skype and google suite. Looked at some cloud computing options that will be used by us to lighten the load on the mobile phone. we also discuss how will be establishing a connection to the Smart Hub to make it secure from hackers with malicious intent by using Wi-Fi direct, as our mode of communication from the application to the devices. Different method of regulating the power consumed by the system was discusses at great lengths, to protect the circuit from being destroyed from spikes in power which can be very problematic. Research on the construction process of the PCB was mentioned to give the reader and us a better understand of how this is done.

The section after the research section we examined the design and prototyping of the smart Light Hub system. the design section comprised of the hardware design where an elaborated explanation of the circuit design was made. The section also had the circuit schematic made in eagle cad. For the electrical engineer using the software was a learning curve since UCF does now have a circuit cad class available for its students. The section when its depth about the software design of the mobile application using fundamental software models to illustrate the process of creating the software. After the design section the prototyping followed. Where the development of the mobile application began. Having this gives the reader the chance to better understand how the application is going to work. The prototyping of the circuit was also done in that section were electrical engineers started to do testing to make sure the design is going to work. This can cause a lot of problems if not done after designing the schematic layout of the circuit. especially if the PCB has been printed. Then the process will have to be done all over again. The last part of that section showed the reads the design of the light enclosure and explained how the light enclosure will be manufactured.

The final sections of the paper talked about how the system will be tested the administrative content. In the testing section the testing plan of the system was write of the software to ensure that everything is working. Also the process to test the hardware components of the system was also discussed. Testing is very important when design a large system. Lastly the administrative section discussed the milestones of the project and budget. Milestone are important for project to hold everyone accountable of getting tasked done to keep the project moving forward.

To conclude, for most of the members in the group it was the first that we have worked on a project of this scale. With members from different engineering disciplines. It was quite a learning experience as we will be transitioning into working environment that primarily consist of larger project where to might not have the opportunity to meet with the entire team of the people that make the project possible. This project has given us a better understanding of group dynamic and how to work with different personality type. Also, giving us a prospective of how to use a member’s abilities to the team’s advantage to the get the most out of them. The lessons learned from senior design will follow us from our entire career not only helping us progress in are career but these lessons can be applied to are everyday life.

10.0 Appendices

The Appendices section of this paper is comprised of two important sections, the bibliography and permissions section. The bibliography made up of all the material referenced throughout writing the paper to give credit where is due and the permissions section has contained all the granted permissions for diagrams, figure and tables.

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univ@ti.com

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Ryad Hafeez
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info@raspberrypi.org

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Kevin Patel
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customerservice@sparkfun.com; Kevin Patel <kevinpatel9082@gmail.com>

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KP

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ntec-support@makeblock.com

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Makeblock Support <ntec-support@makeblock.com>
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Ryad Hafeez; Support <support@makeblock.com>

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Dear Ryad,

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Don't hesitate to let us know if you have further question.

All the best,
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Choose Your Product *

ESP-WROOM-02

Name *

Ryad Hafeez

Job Position *

Electrical Engineer

Company *

University of Central Florida

Corporate Website *

acdtelecom.com

Country *

United States

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Phone *

4079629600

Question/Inquiry *

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Ryad Hafeez
Today, 9:45 PM
support@tronixlabs.com

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Thank You very much,

Ryad Hafeez
(407)-962-9600
rhafeez@knights.ucf.edu

John Boxall (Tronixlabs)
Apr 27, 11:49 AEST

Go for it.
Also see http://www.esp8266.com/wiki/doku.php?id=esp8266-module-family

---

Ryad Hafeez
Apr 27, 11:46 AEST

Good Evening,

My name is Ryad Hafeez. I am an electrical engineering student enrolled in senior design at the University of Central Florida. I am writing this email to request the permission from your company to reference figures/information for the ESP-07 Wi-Fi module from technical documents in a design paper that will not be published.

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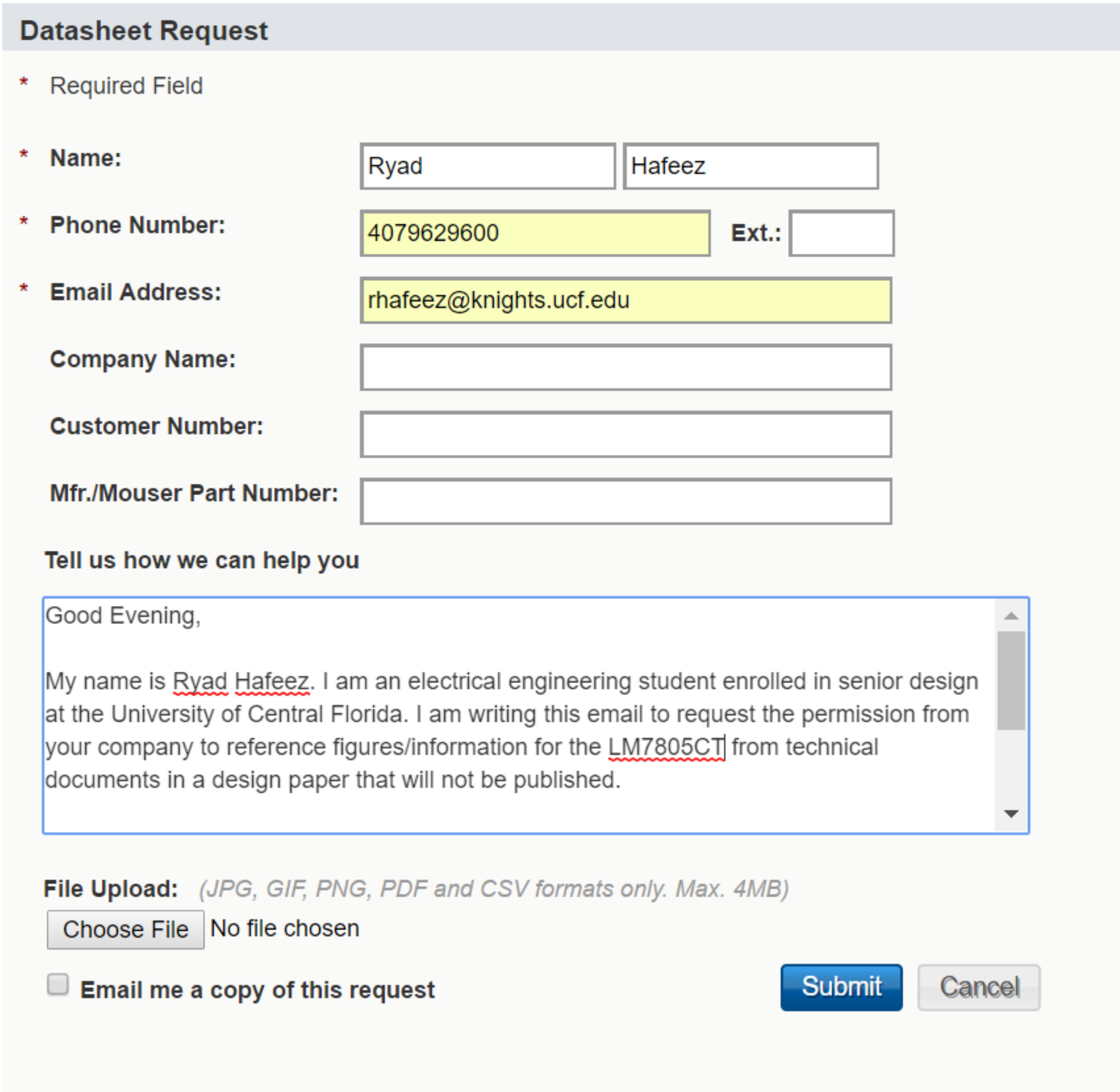
My name is Ryad Hafeez. I am an electrical engineering student enrolled in senior design at the University of Central Florida. I am writing this email to request the permission from your company to reference figures/information for the Linear voltage regulator and switching voltage regulator from technical documents in a design paper that will not be published.

Thank You very much,

Ryad Hafeez
(407)-962-9600
rhafeez@knights.ucf.edu



Datasheet Request

* Required Field

* **Name:** Ryad | Hafeez

* **Phone Number:** 4079629600 **Ext.:**

* **Email Address:** rhafeez@knights.ucf.edu

Company Name:

Customer Number:

Mfr./Mouser Part Number:

Tell us how we can help you

Good Evening,

My name is Ryad Hafeez. I am an electrical engineering student enrolled in senior design at the University of Central Florida. I am writing this email to request the permission from your company to reference figures/information for the LM7805CT from technical documents in a design paper that will not be published.

File Upload: *(JPG, GIF, PNG, PDF and CSV formats only. Max. 4MB)*

Choose File No file chosen

Email me a copy of this request

Submit Cancel

Thank you for contacting us.

A Mouser team member will respond as soon as possible.

Technical Support Team
Mouser Electronics
1000 North Main Street
Mansfield, TX 76063
USA

Phone: (817) 804-3888
Toll Free (800) 346-6873

Office Hours (M-F):7am to 8pm CST

Thank you for contacting Mouser.

****

Comments: Good Evening,My name is Ryad Hafeez. I am an electrical engineering student enrolled in senior design at the University of Central Florida. I am writing this email to request the permission from your company to reference figures/information for the LM7805CT from technical documents in a design paper that will not be published.Thank You very much,Ryad Hafeez(407)-962-9600rhafeez@knights.ucf.edu
Customer Number:
First Name: Ryad
Last Name: Hafeez
Company Name:
Phone Number: 4079629600
Email Address: rhafeez@knights.ucf.edu
Mfr./Mouser Part Number:

Contact Us

Contact the Electronics Tutorials Team

We always encourage you to share your ideas and improvements with us, so if you have any questions about our Electronics Tutorials website, please feel free to contact us using the form below. Many thanks for your show of support.

Ryad Hafeez

rhafeez@knights.ucf.edu

Permission to use figure for Technical Document

Your Message (required)

My name is Ryad Hafeez. I am an electrical engineering student enrolled in senior design at the University of Central Florida. I am writing this email to request the permission from your company to reference figures/information for the crystal oscillator from technical documents in a design paper that will not be published.

Thank You very much,

Ryad Hafeez
(407)-962-9600
rhafeez@knights.ucf.edu

SEND

Contact Support

An Order Placed at the Store

Describe your question below and we'll get back to you within 2 business days.

(* required field)

First Name *

Ryad

Last Name *

Hafeez

Email *

ryadhafeez@gmail.com

Confirm Email *

ryadhafeez@gmail.com

Phone

Include country code and area code.

Order Number

Product

Select...

Description *

Please provide exact steps to reproduce the problem and a description of the expected result. Include specific examples, related datasets and error messages, if applicable.

Good Evening,

My name is Ryad Hafeez. I am an electrical engineering student enrolled in senior design at the University of Central Florida. I am writing this email to request the permission from your company to reference figures/information for the schematic designs that are being developed by our group using the technical documents in a design paper that will not be published.

AUTODESK.

Dear Ryad Hafeez,

We're following up on your support request to let you know we created the case below:

Case 12923285 - An Order Placed at the Store

At any time, you may add information to your Case by simply replying to this email. Be sure to include this email in your reply, so that your comments are automatically updated in your Case.

Thanks for contacting Autodesk for support.

Best regards,

Autodesk

More Options for Support
Here's a list of the support resources most visited by other customers. If there's no time to wait, you may find your answer here:

Subscription Solution Center: Support articles for logging in and managing users and contract information.
Autodesk Knowledge Network: Search for technical support and learning content by product.
Autodesk Community: Find solutions posted by Autodesk technical support specialist and Expert Elite Community members.
Installation and Licensing Forum: Discussion group dedicated to helping you get your software installed, registered, and running.

AUTODESK.

Hello from Autodesk,

Thanks for contacting Autodesk for help with your Autodesk Software. Resources for the Education Community are available here:
Student Community

The terms and conditions for educational products are on our website:
Definition of Educational Purposes

In case of further questions you can contact the education community here:
http://www.autodesk.com/education/support/edu-contact-us-form

see also: Permission to Use/Display Autodesk Copyrighted Materials
further questions email to permissions@autodesk.com

Franz Gaisbauer
Autodesk
CaseNo:12923285.

LIFX

Submit a request Si

How can we help?

Search our articles

Express Support

A guided approach to support

0

i. Tell us what's going on *

Specifics count here, the more information we have the quicker we can work to resolve your request.

To add a paragraph, press **SHIFT** + **ENTER**

My Name is James Harrison I am a student at the University of Central Florida, I was wondering if I could use the LIFX Bulb image for my senior Design Paper. Thanks, James

Welcome to the Philips Lighting inquiry service. Please complete the fields below so we can answer your inquiry in the best possible way.

Fill out the contact form

Who are you

- ○ I represent a company
- ◉ I am a private person / consumer

What is your question / comment about?

- ◉ Purchasing prices, orders, replacement, quotations, product application, brochures
- ○ Products you own, manuals, registration, complaints, warranty

* Your question

Hello My name is James Harrison I am a student at the University of Central Florida, I was wondering if I could use the attached image for my senior design paper.

Thanks

Upload your documents

Drag and Drop here

Please attach the file here

1). Screen Shot 2017-04-26 at 11.34.31 PM.png

James Harrison Sent - School 11:39 P

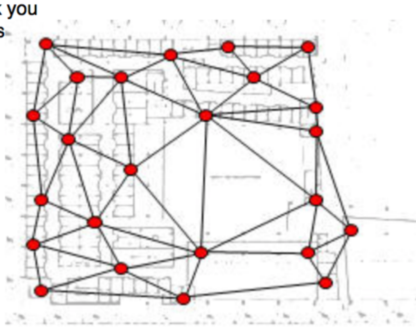
Senior Design Permission

To: marketing@zigbee.org

Hello My Name is James Harrison

I am student at the university of Central Florida, I was wondering if it would be ok for me to use the attached image in my senior design paper

Thank you
James



You have 5 questions remaining.

Component: Functions

Project (optional): Select a project

Urgency: Low

Summary: Permission to use images

Description:

Hello,

My name is James Harrison a Computer Engineering Student at the University of Central Florida, I was wondering If it would be ok if I use the attached images from the firebase and google cloud functions webpages for my senior design paper?

Thanks
James Harrison

Attach Files: Choose Files 3 files

Your request has been sent.