Solar-Powered Wi-Fi Umbrella

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***Abstract* – The worst thing about the outdoors, is that there are very limited locations to access Wi-Fi. What if it was possible to enjoy tanning at the beach, or working in the yard with music streaming, or even walking down the sidewalk without having to use up the precious and rather expensive data from the cell phone companies? With the Solar Powered Wi-Fi Umbrella, it could soon become a possibility. Combining everything that is great about being inside with the beauty of being outside will soon be a far off distant memory.**

***Index Terms* – charging stations, LED lamps, solar panels, solar power generation, wireless LAN .**

I. INTRODUCTION

With the constantly evolving technology today, the internet is both more wanted and needed than ever before. Imagine a world where everyone has access to the internet always. Walking down the street to stream music, in the park to watch a movie while on a picnic, or even being able to play those addicting mobile games at any location, at any time. As the demand increases for internet access, the price to attain that access is also increasing. Cell phone companies are taking full advantage of the demand, and charging an unreasonable amount for their data plans. What if all of family sharing their limited data, just for it all to be used up halfway through the month because one certain person accidently forgot to turn their Wi-Fi on when they got home.

The idea is to provide reliable internet access to areas that would normally not get any. A bonus is that it would be completely self-sustaining getting its power from the sun, and running off a rather powerful battery that is sure to last through the night. Speaking of which, the umbrella will be equipped with several LED lights that will illuminate the immediate area as if the sun is out. Adding both a function of practicality for night time use, but also a safety feature should the situation arise.

The ability to access the internet is a basic human right, and all who are able should take advantage of the many remarkable things it has to offer. Humans have spent their whole existence trying to perfect the indoors, and the outdoors seemed to have gotten neglected, which could prove to be disastrous for us all. Why not take the best thing to happen inside since air conditioning, and bring it outside while there is still an outside to enjoy? Hopefully this umbrella will not only protect small children from the harmful rays of the harsh sun, but also give them a reason to want to be outside. We want to make being outside great again!

II. COMPONENTS of UMBRELLA

Like many other types of project there is never just one component that makes up the entire project and this umbrella is no different than all the others. As such, this umbrella has various components that each do something different and are necessary for the umbrella to function the way that it was envisioned. Hence forth, the sections underneath will talk about a general detail of each for the components that make up this umbrella project.

A. Solar Panel

The inclusion of the solar panels is a straightforward addition in that because the project will be powering up various devices there will need to be a way to charge these devices and this is the reason why the solar panel was chosen. Alongside, the fact that the world is moving forward and using more renewable energy sources to power our day to day electronic appliances.

B. PV Controller

A solar panel cannot work without a PV controller of sorts to control the amount of power that the solar panels produce. This controller will also help in powering the battery of the umbrella.

C. Lights

The lights in this experiment are more of an aesthetic design that was included to make the umbrella appeal nicer. However, a level of complication was included to them since they will be controlled by a type of microcontroller.

D. Wi-Fi Extender

This is arguably the most important component of the umbrella because it was the origin of previous ideas that were used to create a Senior Design project

and was the only one that was kept in the end because of the idea of making the world have easier access to Wi-Fi and one way to achieve this is with a Wi-Fi extender.

E. Battery

The battery will provide a form to charge any of the components attached to the umbrella even while the solar panel is not active. To light up the lights and keep the Wi-Fi extender powered up during the night.

F. Inverter

Inverter is a component that takes DC or AC input and convert it to an AC or DC output respectively. However, for this project an AC output is needed because the devices that will be connected to the charging station all operate in AC unlike the battery and PV controller that emit DC power. This inverter would also serve as a power outlet for the components that will be connected to the umbrella and charge the other components previously mentioned.

G. Light Controller

The lights will be controlled by using an Arduino Uno Microcontroller. This controller will have sunrise and sunset values and according to those values in comparison with the current time the lights will turn on and off. Additionally, a Real Time Clock board as well as a 4-channel relay board were used in our implementation and will be further detailed in the hardware details section below. An emergency functionality has been added which flashes the lights for 5 minutes to call attention to the umbrella.

H. Emergency Call Button

In case of emergency the umbrella will have an emergency call button. This will be set up to call local authorities in case of an emergency. In accordance with the flashing lights from the emergency lights this should be a major safety feature of the device.

III. CONCEPT of UMBRELLA

Harnessing the power of the sun is the key to this umbrella. With the direction renewable energy is going, solar power will increase in popularity, and in return, the efficiency of said panels will also increase. Currently the panels operate at a 20% efficiency, and those are the best of the best panels. It must also deliver something practical. Amplifying a wireless network signal will prove to not only be a challenge, but a great reward. The internet is a useful resource, and it is not known how dependent on it we all are as a society until it cannot be accessed.

The umbrella, shown in *Figure 1*, will collect the energy from the sun with the four solar panels on top, send the energy through the PV controller which will 'regulate' the voltage by making sure that it does not exceed a certain amount and damage whatever component is added to it which (for this project will be the battery and the microcontroller). The battery is also capable of powering the controller whenever the solar panels are having problem obtaining any sun be it because it is nightfall or is a cloudy day, as well as the DC to AC 12V to 120V inverter. The inverter will be equipped with two outlets, and two USB ports which will power the Arduino Microcontroller, as well as the wireless amplifier alongside any other component that the user would like to attach such as a phone, tablet, or even a laptop. The general idea on how this umbrella would look like can be seen in *Figure 1*:

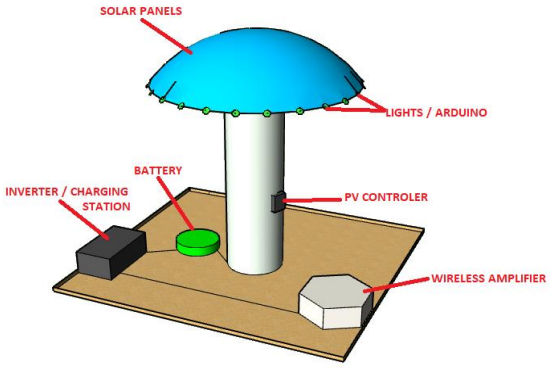

Figure 1: 3-D View of the Umbrella Project

Bear in mind that the diagram in *Figure 1* will not be the exact same as the final product but more of a rough 3-D sketch on how the umbrella would look like. An example of this would be regarding the base or the bottom portion of the diagram. In Figure 1 the base is large while in the final product the base is just a little bigger than the pole of the umbrella. Which speaking of the umbrella the actual umbrella would not look like that design but instead of a more traditional umbrella found in patios and backyards of houses.

IV. HARDWARE DETAILS

Unlike the previous section that just talked about the different components that will help form the project this section gets into details about not only the

component but also the specific pieces used for each of the different areas.

A. Solar Panel

For this project, various solar panels were compared but ultimately the solar panels that won our vote were the Monocrystalline variation for the sole reason that the other option, Polycrystalline, was not necessary for a project of this caliber and the pricing was higher. As for the specifics, the best variation was the bendable option since they will be placed in the canopy portion of the umbrella and will need to be bendable in the instance the umbrella is folded and placed in a location with little room for the solar panels to be placed.

The model that was ultimate decided upon was the ALLPOWERS 100W 18V 12V Bendable Flexible Solar Panel Charger. Reason being that it satisfied the needs of this project since they were small/medium size and gave the needed charge to not only power up the battery but allow the umbrella to use all the other features embedded inside without the worry of the umbrella struggling with power to perform certain functions.

B. PV Controller

One cannot talk about the solar panel without also talking the about the PV controller because one cannot function without the other (at least without any complications occurring) because the solar panels absorb the sunlight and convert it to electrical energy however without the PV controller to properly control and manage this new energy any component attached to the solar panels directly can result in that component getting destroyed or damage.

Regarding the specifics of the controller, the option that was decided amongst the group was to create a simple version to compare to one of the more advanced models that one of our members had before the project started. Details about this controller will be better explained in *Section V* of the paper. However, to differentiate this homemade PV controller and a regular controller another more professional controller was included in the project scheme to showcase and compare the inverter. The exact controller that will be used to see how proper the homemade PV controller works is the MOHOO 20A Solar Charge Controller Regulator. This controller takes the power/voltage that is created from the solar panels and transfers it to the battery while making sure not to overcharge the battery in the process. This controller also carries a LCD display that shows the actual charge of the controller to the batter, in other words it sort of works like a multimeter between the battery and solar panels while also displaying whether it is charging or not.

C. Lights

The lights in this project are going to be some LEDs attached to the rib portion of the umbrella but what makes them special is that they are connected to a microcontroller that will turn them on or off and even alternate the on/off sequence. The LEDs that will are going to be mounted to the ribs in the umbrella are a cool white illumination with a 600mA-700mA / DC 6V-7V / 5 Watt. Each individual LED weighs and is about the size of a quarter.

As stated previously the LEDs are going to be connected to a microcontroller that will turn them on or off. The microcontroller that will be turning them on or off is the Arduino UNO Wi-Fi. However, *Section V* of the paper will talk more about the Arduino and all the coding revolving the turning on and off the lights while *Part G* in this section will talk about the more specifics of the microcontroller.

D. Wi-Fi Extender

The device that will provide this project with the ability to extend Wi-Fi signals is the Netgear Nighthawk AC1900 Wi-Fi Range Extender. The reason why this device was chosen was because it was reliable when it came to maintain the extension of Wi-Fi signals unlike the others. As for the reason why a Wi-Fi extender was chosen over another form like Mobile or Satellite is because these other devices would be more complex in trying to show a successful project.

Due to the Wi-Fi extender being a large integral of the project the specifics of it need to be explained to showcase that the Netgear chosen was a great selection. First, the extender will have the capabilities of Wi-Fi speeds up to 1.9Gbps which is amazing considering how low the bps is in the US. Extender can use both imbedded Wi-Fi bands to establish one super high speed connection which improves the overall signal. Another, great feature is that can extend the Wi-Fi signals of up to 600ft (tested by one of the members before running out of walking space in the testing area). However, this is not the maximum amount in which the extender can extend the Wi-Fi nor will this be the limiting number for this project since larger antennas were also bought that can greatly extend the Wi-Fi signals to a large enough area.

E. Battery

For this project, the battery is vital because when the solar panels are not receiving any sunlight they would not be able to power any section of the umbrella and is the reason why a good battery was needed to be selected. When comparing the different batteries there are two types a lead-acid battery and a lithium-ion battery.

Lead-acid batteries are great due to their price. They are significantly cheaper than the lithium-ions, but it comes with some very unfortunate negatives. The lead-acids, as the name suggests, tends to emit a rather toxic gas as it is being charged. Because of this they need to be kept in a well-ventilated area to eliminate the chance of endangering anyone. They are often found in battery backup systems, or as the battery in a car or truck. They are perfect for delivering that initial high voltage to start, and then the voltage quickly dies. They also tend to be on the heavier side, which would make things rather inconvenient should

As for the Lithium-ion batteries, they are the most popular rechargeable battery for a reason. Used from cell phones, laptops, tablets, electric cars, and now thanks to Tesla, they are even found in a battery backup system for a home in case of a power outage. The most convenient thing about the lithium-ions is their efficiency. Our current battery, the 12V 10Ah Dakota lithium-ion battery, delivers a constant 12.8 Volts, and will continue to do so until it dies as seen in *Figure 2*. It was imperative that we had a battery that would function through the night just in case the need arises to spend the night under the stars surfing the web.

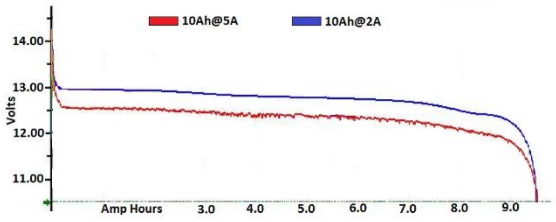

Figure 2: Voltage output duration for Lithium-ion battery

Unfortunately, the great efficiency comes at quite a price. Not only are the lithium-ions a lot more expensive ($120 for this battery) than their lead acid battery, but you get what you pay for. The current biggest issue seems to be the explosions that are occurring within the batteries causing not only harm to the users in the case of the Samsung Galaxy Note 7, but even more worrisome is the potential for terrorists to use the seemingly harmless batteries as a bomb to bring harm to the innocents. To prevent such an accident, the PV controller will monitor the charging of the battery to prevent overcharging, which will prevent overheating, and which in turn will eliminate any danger that may arise.

F. Inverter

Originally there was going to be a separate charging station that had the wall outlets for the Wi-Fi extender alongside any other component that can be attached to it however the decision was made to find an inverter that had the functionality as the charging station to remove it from the final list of components needed for the project. That is why after some comparison the “Bestek 300W Inverter” ended up being the clear choice out of the other inverters because of the good reviews that it obtained plus the pricing for the functionality was perfect. However, reviews and price alone are not a good enough reason for this product to be selected for this project but instead the functionality that it has was the reason why it was selected. The reviews and the pricing were a good bonus.

As the name states it is a 300W inverter and how it was stated in the *Section III* the inverter will take a DC input and convert it to an AC output. For this project, the input would be 12V DC while the output will range anywhere from 110-120V AC. This 120V AC is the standard voltage in the US for all electronic appliances that are connected to a wall socket.

G. *Light Controller*

As mentioned above the basis for our light controller is an Arduino Uno board. This makes use of an ATMega328 microcontroller which is adequate for this application and what we need this board to do. For our purposes the controller will run without monitoring but for the purposes of maintenance, if a computer is plugged into the controller the user will be able to change the sunrise and sunset times used. This will allow for maintenance and flexibility of the controller.

To the basic Arduino we added multiple components in order to achieve the desired functionality. The first component added was a Real Time Clock Module Board. After some research, we chose the SainSmart RTC DS1307 because of its wide use and stability. This board give the Arduino the ability to keep time accurately. Additionally, this

board has an onboard battery so if the unit is powered off it does not lose track of time. As a result, the next time the Arduino is powered on the time will still be kept and accurate. In the context of this project we use this in order to check the current time and compare it to preset sunrise and sunset times. These will be compared to the current time in order to determine if the lights should be turned on or off depending on the time of day.

The next component added was a four channel DC Relay module. After considering the options and determine the needs of the project we landed on the JBtek 4 Channel DC 5V Relay Module. This module allows the microcontroller to turn on and off the 4 relays which will control our four LED light strips. This will allow us to control the lights in different ways such as an emergency functionality that has been implemented. This functionality will be triggered by a button which will be easily accessible to users. Once the button is pressed the lights will flash in al alternating pattern for five minutes in order to call attention to the umbrella. We believe that this in conjunction with the emergency call button will help keep areas where the umbrella is deployed safe.

These components have been combined along with a button to trigger the emergency mode mentioned above as well as other connection components into one cohesive and reliable system.

H. Emergency Call Button

This emergency call button will be implemented with an Amazon Dash button. These buttons have been made popular by Amazon and they allow users to press a button and an order for a specific item is placed. We will be using a 1st Generation AWS IoT Button which provides similar functionality as the buttons used for the Amazon service, but we can change what happens when the button is pressed. Here we will implement the emergency call or message functionality by way of a stable and effective platform.

V. SOFTWARE DETAILS

This section would not only talk about the coding and any necessary aspects about the microcontroller needed but also the controller of the project since to create the PCB schematic of the controller a software was needed to be used.

A. PV Controller Schematic

Due to the requirements of a PCB being needed for this project the controller was decided upon as the PCB since it was the least complicated option or the one that will not destroy any of the components in the umbrella unlike the inverter, who was the original idea of a PCB. Due to a PCB being created it needs to be sent out to a manufacturing company and to send it to a manufacturing company a computer file needed to be submitted. The creation of this file was done using a PCB schematic program (for this project KiCad was used). As for the exact circuit schematic that is going to be used can be observed in *Figure 3* that is located at the very end of the paper due to how large the schematic for this circuit is and because it will cause some complications and confusions in the paper. However, that will not deter from talking about it.

The circuit is a simple circuit that just makes sure that the solar panels charges the battery without overcharging them. A display was not included, unlike some other standard PV controllers, in this schematic since it was observed as a limitation since it required a lot of man power that could have been used in including more features or making sure that the current features worked properly. But to counteract this decision a multimeter is used to compare the two different PV controllers and to showcase that PCB variation of the controller does the job it was designed to do.

However, the circuit has a relay and a timer that will work like a comparator that will compare the voltage of the battery to see if it falls below a certain threshold, for this experiment it will be roughly 9 volts, and if the comparator sees that the battery fell below the 9 volts the relay will start charging the battery. This charging will utilize two different colored LEDs that will help indicate to the viewers when the circuit is charging the battery and if it is not charging the battery. These LEDs combined with a multimeter will provide the same results as if a display of any sorts was being used.

B. Light Controller Code

Light control is handled by the Arduino mentioned above with the appended modules, all controlled by the code written. The first piece of the code imports the libraries needed for control of those components as well as to include other functionality that we are using here. We then define various variables that will not be changing throughout the code as well as global

values that will be used throughout different parts of the code.

Next the Arduino has a setup function that is automatically run when it is powered on a single time. This section of code starts by initializing the Serial port for the console. Next, we initialize the Wi-Fi and the real-time clock. Operation of the real-time clock is then checked and if not working is reported back to the console and the time is set. Next the program prints 3 things to the console: the time the Arduino was turned on, the set sunrise time and the set sunset time. These values being outputted to the console can be seen in *Figure 4* below. Next the values for the relays are all set to be off by default. Lastly the pins which control the 4 relays and the button are all set as input and output accordingly.

Figure 4: Arduino Console

The next the Arduino will jump into a loop that runs indefinitely in the form of a function called loop. Here we retrieve the current time at the beginning of every loop in order to keep it updated. Next the code checks if the current hour is greater than the sunrise hour, if the current hour is less than sunset hour and if the lights are on. If this is the case it checks if the current minute is greater than the sunrise minute. This would indicate its time to turn off the lights, which will be done in a sequence. The flag that indicates the state of the lights is set to off and lastly it prints to the console with the time the lights were turned off. If this option was not true then it checks the next option which is that the lights should be on, this is checked similar to above and the lights are then turned on and the steps after follow like the prior.

The last component of the loop is the emergency button check and the time change button check. If the emergency button is pressed it would trigger an emergency function. This function prints to the console that the button is pressed and the time it is pressed. The lights then flash in an alternating fashion for five minutes. After this is over the lights default to turn on and then the loop runs again so depending if it is day time or night they will stay on or turn off as needed. In the case of an emergency the button can be pressed again and it would run again.

Alternatively, if the change time button is checked then the user will be prompted via the console to make changes to the set sunrise and sunset times in the system. This will be useful so that people upkeeping the device can change those values as needed since sunrise and sunset times may change over time and need to be adjusted. After the button is pressed the console will ask the user if they want to change the sunrise time, sunset time or cancel the change request. If they choose sunrise or sunset they will be asked to enter the hour (0-23) and the minute (0-59) and then these values will be updated. They should then be checked and updated right away so that the state of the lights is changed accordingly.

VI. PROJECT RESULTS

Unlike other projects that can show results using an oscilloscope or proper images the results and their respective images in this section had to be taken in a cellphone camera due to this project needing to be tested in the outside while a good camera was not available. So, Group 7 apologizes for either the lack of images or the inclusion of not the best images.

Speaking of images *Figure 5* below shows the MOHOO PV controller that has connections from the solar panels and the battery. While showing that the power obtained from the solar panels is a little over 12V which is enough to keep the battery from getting drained during the day time and keep it charged for when it is used in the nighttime.

Figure 5: Testing 1

As for the PCB controller, it is hard to test it since it functions on DC power so it would just be another picture of a multimeter like the one above that showcases the MOHOO controller.

Other than, connecting a PV controller to the solar panels and the battery all the other forms of testing need to be showcased in a video or in person and is the reason why more details about the results, thought process, way of thinking and part pieces were put into *Section 4* & *5* instead. However, this section needed to be included to further explain any other

lose ends and to show that connections work in this project and that it is not just talk.

VII. DIFFERENCE BETWEEN PREVIOUS WORK

Something that must be stated is that this project is not 100% unique and that is understandable since with our current knowledge it is hard to create something that is completely unique. Henceforth, the inclusion of this section to talk and reference these similar products to properly differentiate between this umbrella and other umbrella projects.

In Amazon, one can search up solar powered umbrella and various models will show up. Various with a form of illumination. However, what differentiates them from this umbrella is that non-have or extremely few have Wi-Fi extending capabilities which means that umbrella must be located in an area that has Wi-Fi capabilities or resort to use mobile data in order to use any electronic appliances such as a tablet or phone but when it comes to laptops a problem arises since in order to use laptops a mobile hotspot is required and those can be expensive since laptops are designed like phones and tablets to consume less data.

Another, important feature that the similar umbrellas have is that they only have a small, 6 inches typically, solar panel that gets enough power to light up the LEDs at the push of a button and the charging station. Something in which this umbrella does differently since this umbrella will have 4 different solar panels since the power needed to potentially charge a laptop is much higher than a phone or tablet and while the LEDs are turned on by a button this umbrella gets turned on by a timer in a microcontroller to last while it is night or the sun doesn't want to show its face. This may sound like a downside however due to microcontrollers getting advancements the possibility of controlling the microcontroller using the Wi-Fi capabilities is only one step away or one functional code and microcontroller away.

Lastly, one of large difference between this umbrella project and others is the inclusion of an emergency button that when pressed will send a message to someone, like the police, to show that someone needs help in the location where the umbrella is located.

IX. CONCLUSION

The future is now thanks to science! Renewable energy such as solar, wind, or hydro power is here to stay, and will only continue to grow with more research and testing. With some proper funding and research, the solar powered Wi-Fi umbrella could be hitting the market before we know it. The need is out there, and could potentially be used in the backyards of the average household, or the local park. Turning an ordinary gazebo, or pavilion into something that provides a service to the public would be the most ideal, and best result possible from this project.

Many things were learned, from programs that were like learning a foreign language, to soldering components together, as well as the best and most efficient ways to communicate and connect with a group of strangers if their end goal is the same. Teamwork and patience played a large part to bring this umbrella to life.

Thankfully only a few problems arouse, such as hardware not cooperating with design, random software updates, and possibly a few electrical shocks here and there. All in all, the project was a huge success, and thankfully everything was implemented as requested. Hopefully one day in the future these will be widely used, and will serve the purpose of making being outside great again.

BIOGRAPHY

Aaron Dobo will be graduating with his bachelors in electrical engineering, and is currently working on Frequency Response Testing for the Space Launch System rocket at the Kennedy Space Center. After graduation, he will be taking a full-time position as part of the Flight Controls team, and is excited to have his name in the future of space exploration

Alan Birmaher will be graduating with this bachelors in Computer Engineering and is currently working for Siemens Energy Inc as a Senior IT Technician Intern. After graduating he is excited to dive into the professional world of software development in the hub of

technological development in the United States, California.

Kevin Diaz will be graduating with a bachelor's degree in Electrical Engineering. After, graduation he is eager to delve into the world of power engineering.

Freddy Artigas will be graduating with a bachelor's degree in Electrical Engineering and is currently working for Lazen power engineering as an electrical designer and drafter Intern. After graduation, he is going to New Jersey institute of technology to obtain his Master in power and energy systems

EXTRA FIGURES

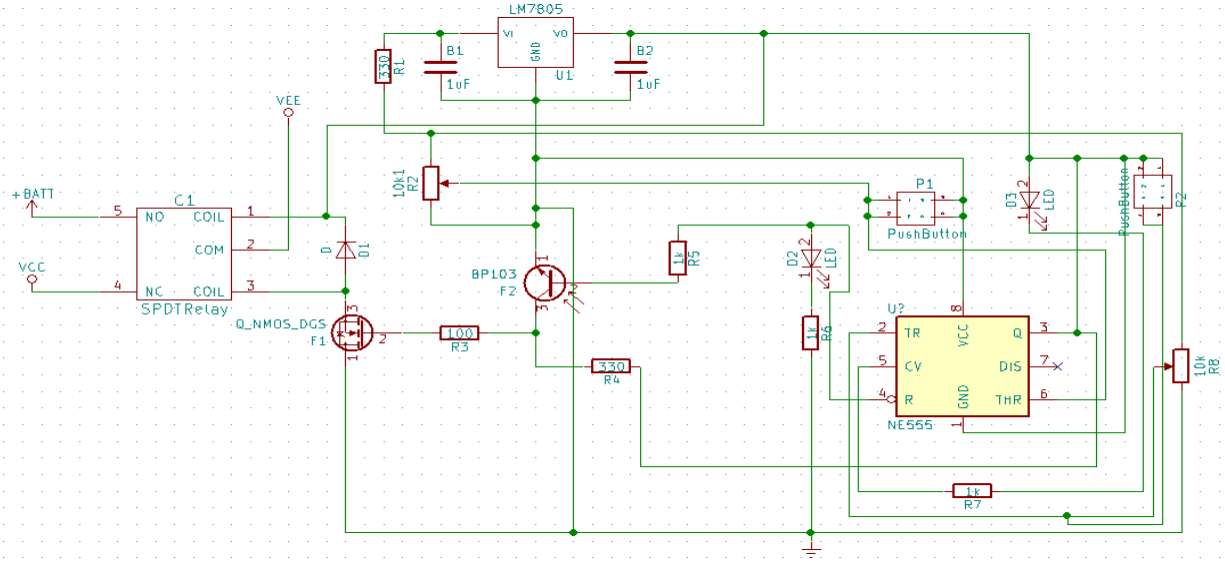

Figure 3: Schematics of Controller