Autonomous Lawnmower

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POWER SUPPLY SUBSYSTEM REPORT

REVISION – 3
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1 Subsystem Introduction

This subsystem consists of all the components that are used to power the Autonomous Lawnmower. This includes the PCB, in which there are two paths, one for signal and one for voltage. The signal path takes the input voltages from both the solar panel and the wall power plug and verifies if the solar panel voltage is between 6 and 15 volts using a window comparator. The output from this comparator is a signal that is used as the MOSFET gate, in order to effectively open or close the MOSFET as a switch. The voltage path is the input to the signal path, but are also to be input to the MOSFET source and is passed through in the according path dependent upon the decision made by the signal path. The voltage then flows through the corresponding MOSFET and diode, which is used to prevent backwards voltage flow, and to the PCB output. The PCB output is connected to the input of the solar charge controller, in order to ensure the battery is safely charged. The connection between the PCB and the solar charge controller is disconnectable in order to ensure that the lawnmower can disconnect from the system when it needs to operate freely. On the mower unit itself, is where the solar charge controller, battery, and connections to other systems will be. The charge controller is wired directly into the battery and the loads to the battery are also wired directly to the battery as some of our loads require very high currents, such as our motor driver which will require 7 Amps.

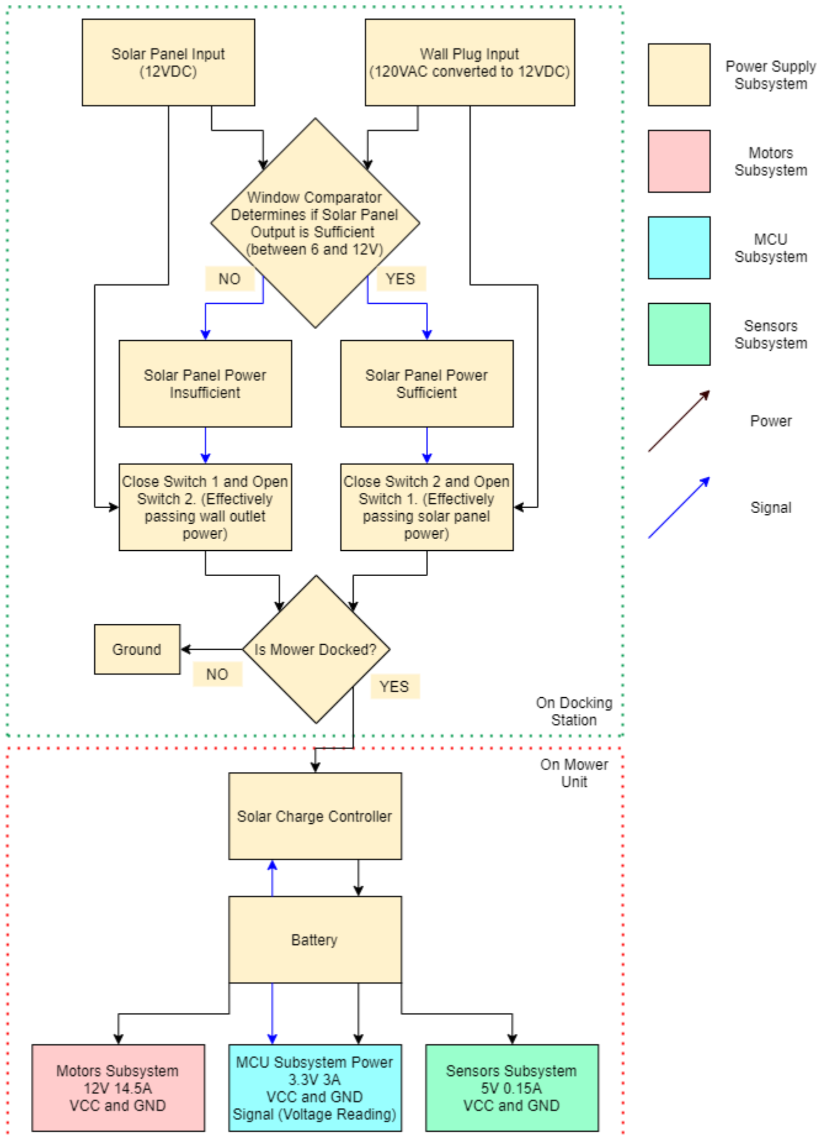

Figure 1: Flow of Signal and Power within Power Supply and to Other Subsystems

The above block diagram represents the major components of the power supply. The top box, represented by green dotted lines, is the portion of the power supply that will reside on the docking station. The bottom box, represented by red dotted lines, is the portion of the power supply that will be on the mower unit. Components on the PCB such as resistors are not included above. In order to simulate the loads I have acquired different wattage landscaping and car lights, which will be replaced by the other subsystems in our application moving forward.

2 Simulation

The first major step in the development of my power supply was the development of my power supply subsystem was simulating the circuit for the determination of which input to take.

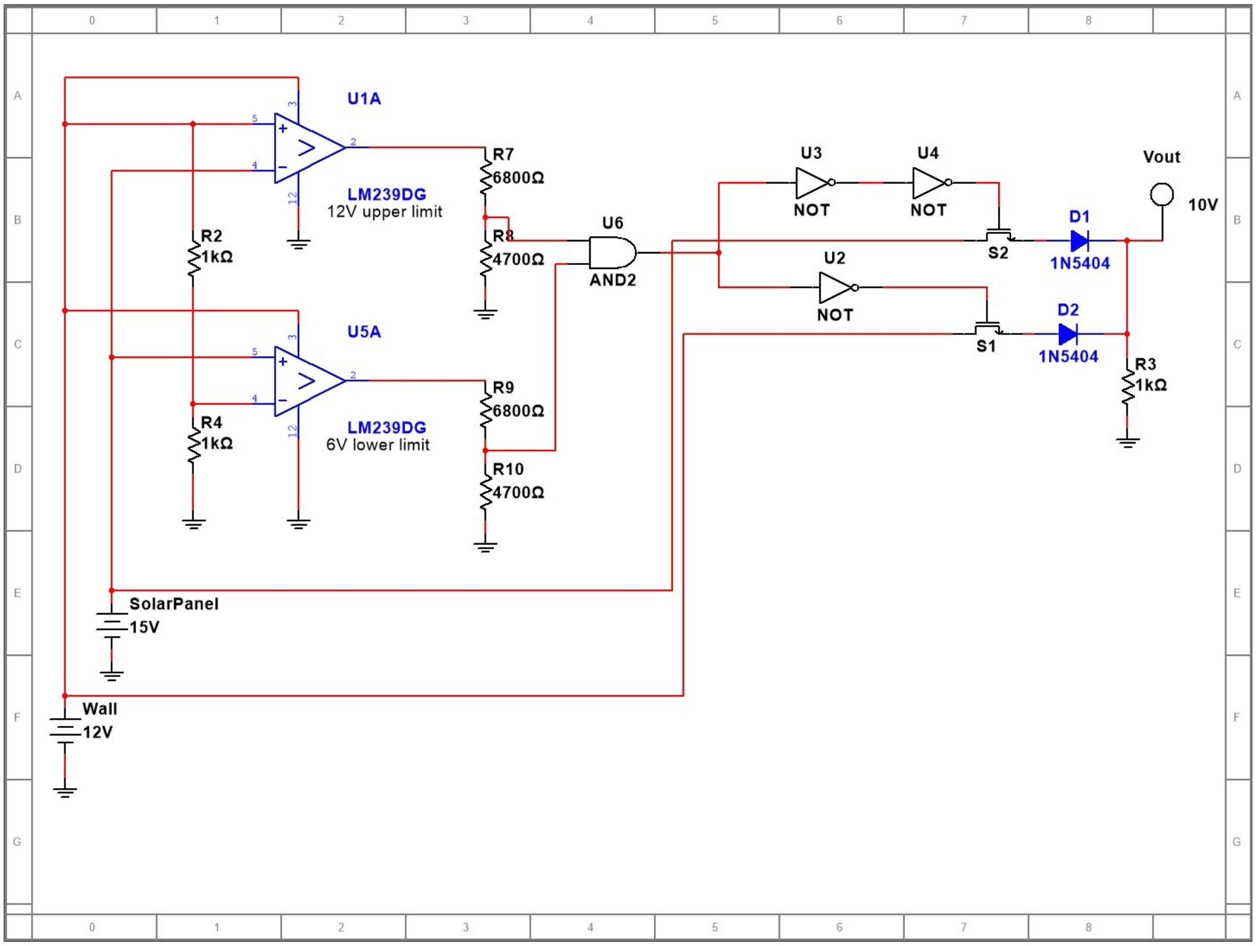

Figure 2: Printed Circuit Board Schematic

In theory, the window comparator should output a high signal for any input voltages in the range of 6V and 12V, exclusive. The comparator can be validated by running a DC sweep, in which the Solar Panel Voltage is varied from 0 to 15V, which is the standard range of a 12V solar panel. Figure 3 below confirms this by showing the solar power path has a high signal for any voltage ranging from 6 to 12V and a low signal for all other voltages. It correspondingly shows in figure 4 that the wall outlet signal is high for any voltage outside the 6 to 12V range and low signal for all other voltages

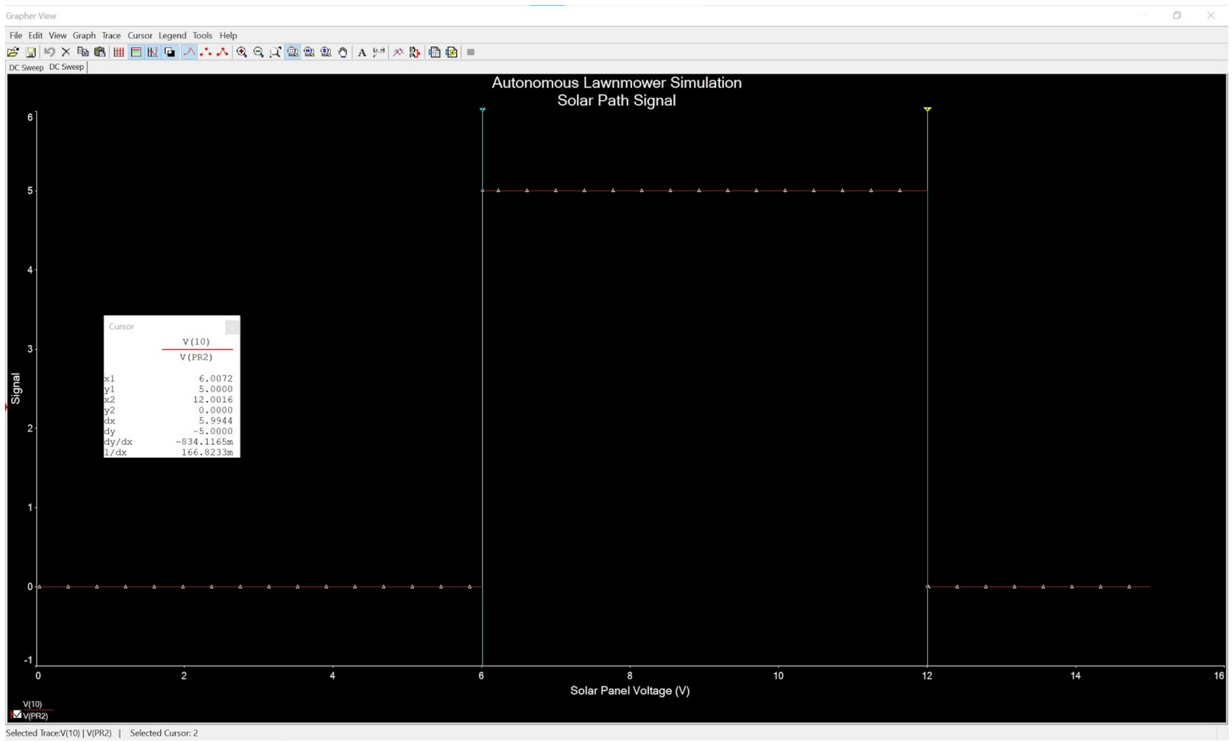

Figure 3: DC Sweep of the Solar Path Signal

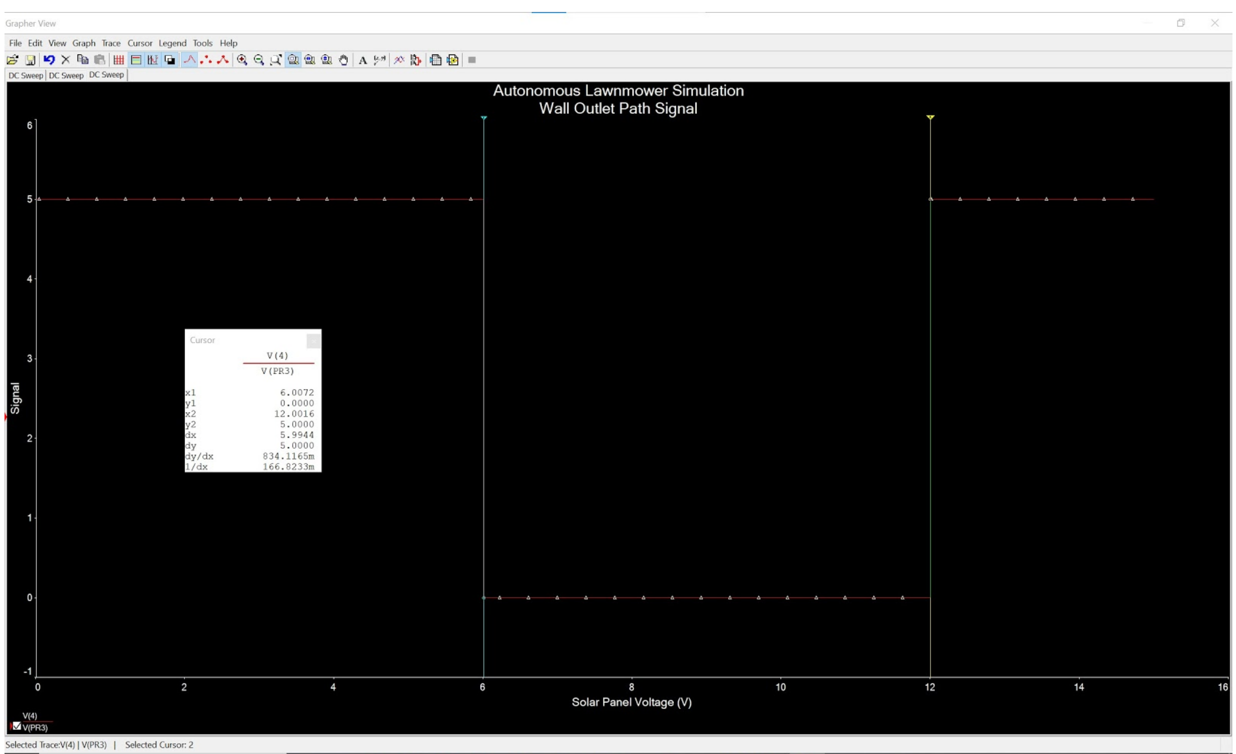

Figure 4: DC Sweep of the Wall Outlet Path Signal

These signals combined tell us which path will be supplying the power to charge the battery for a given voltage of the solar panel. The figure below shows the combination of these two signals, in which we can see the voltage output to the solar charge controller. The

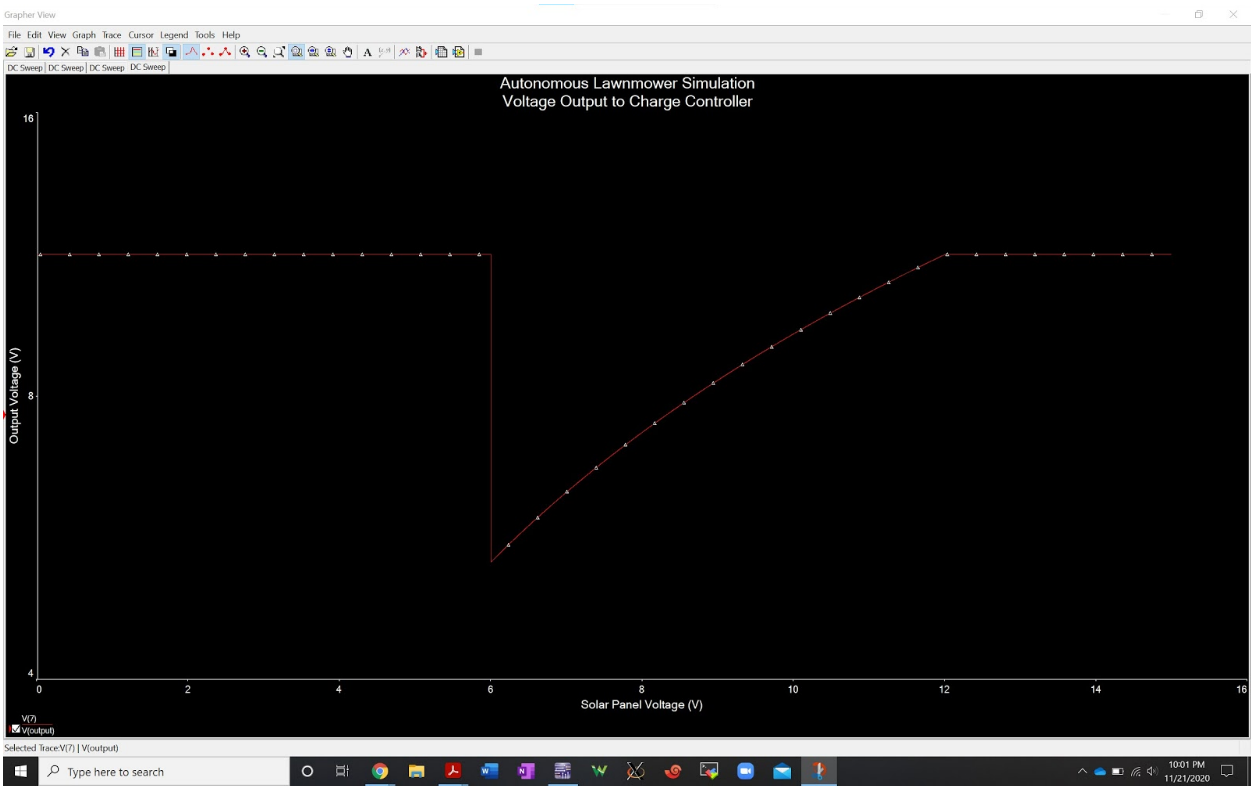

Figure 5: DC Sweep of the Voltage Output that will be sent to the Charge Controller

3 Printed Circuit Board (PCB)

The Power Supply PCB was designed using Altium Designer 20.2.5 as a 2-layer board, in order to reduce overall manufacturing costs. The PCB includes the two comparators that function as a window comparator, screw terminals for input and output ports, resistors, power MOSFETs, diodes, as well as AND and NOT gates used for signal flow. The following two figures show the top and bottom view of the PCB in black and white including the solder pads, traces, through holes, and silkscreen used for part labeling. The original PCB came from Advanced Circuits, but after initial evaluation, it was reordered from JLC PCB as they could produce it for far cheaper.

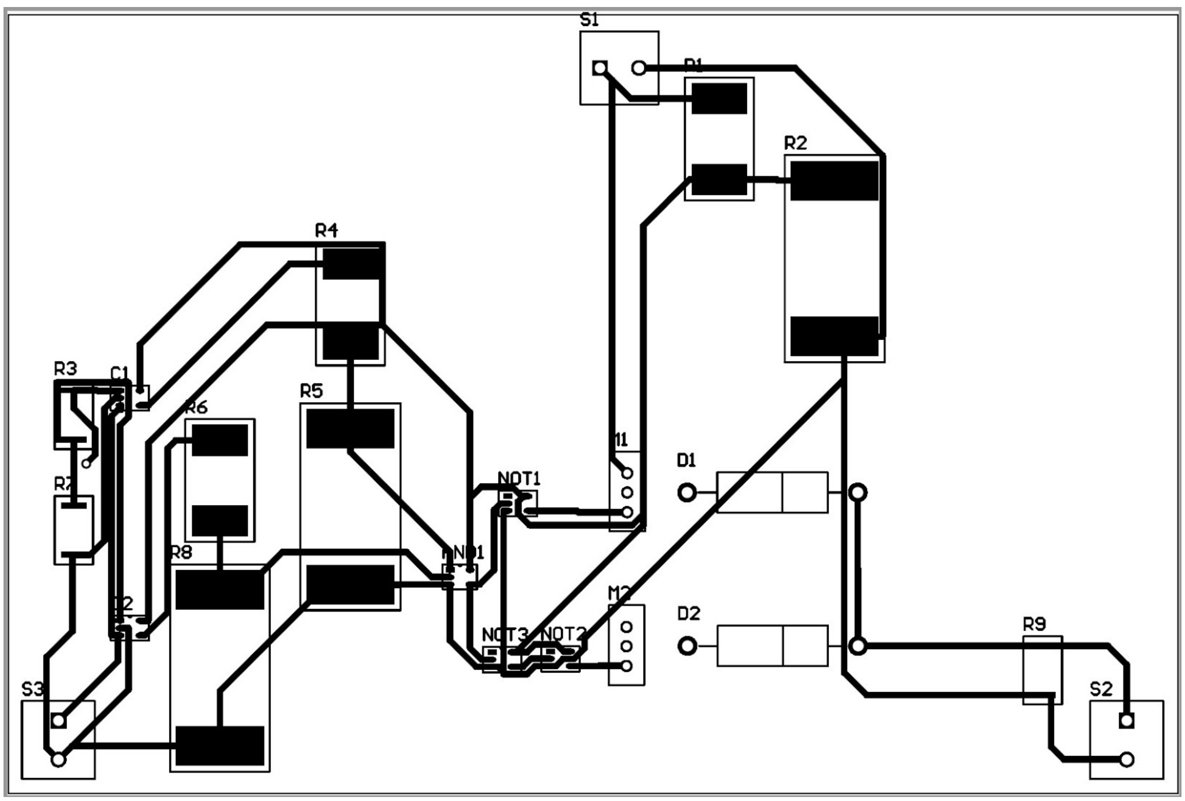

Figure 6: Altium Generated PCB Top View

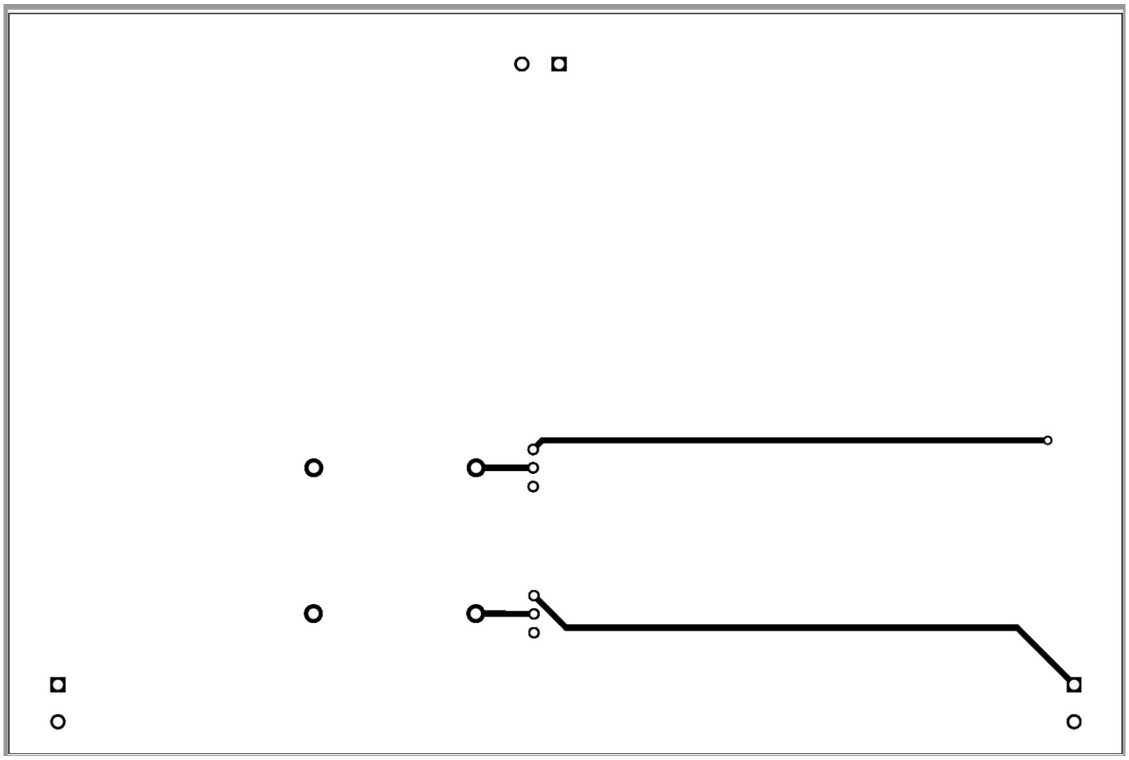

Figure 7: Altium Generated PCB Bottom View

3.1 PCB Evaluation

After receiving the initial PCB and evaluating it some issues became apparent. First, the hole sizes for both the through hole MOSFETs and diodes were too small as I had generated the hole size using the max hole diameter given in the datasheets, but they had been slightly larger than that, within the given percent error. The MOSFET holes also had been corrected to round holes when the pins are rectangular, and in doing so the hole took the diameter from the smaller dimension. Another thing that is worth mentioning but did not create any issues is the fact that some of the traces were right next to each other.

In order to fix these issues I reordered my PCB from a new vendor, JLC PCB, as they could produce the board in about the same time frame, shipping included, but for a much lower cost. They also had a minimum quantity of 5 boards per order, so I was able to have extras if need be as well as to practice soldering on. I enlarged the holes by taking the maximum hole size and adding 3 mil to the diameter for both the MOSFET and diode holes. I also changed my footprints for the MOSFETs to include round holes in which I made sure the diameter of the hole represented that larger dimension, in my case the pin width. Below is the top and bottom view of my final assembled PCB

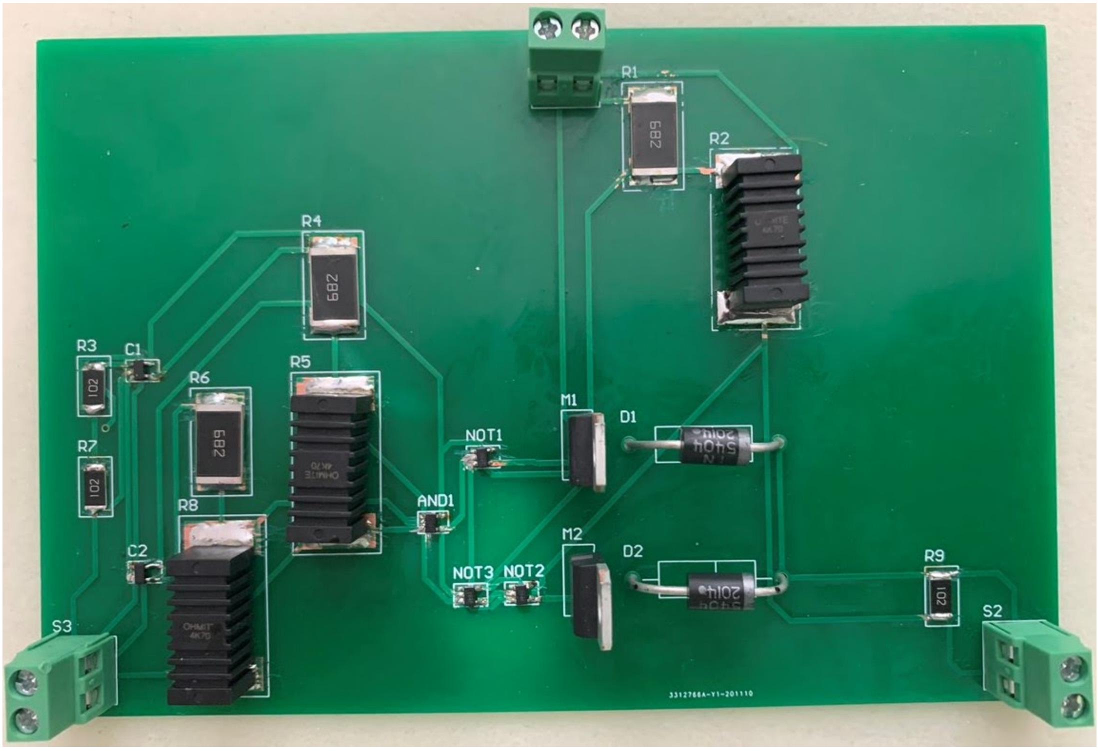

Figure 8: Received PCB Bottom View

Figure 9: Received PCB Bottom View

4 Load Testing

In order to validate my battery size and load values, I had to find a suitable load to test my 3.3V 1A expectation for the Microcontroller Subsystem, my 5V 0.2A expectation for the Sensors, and my 12V 2.42A and 12V 7A expectations for each motor and the motor driver. In order to simulate these loads I used a 12V 100W car headlight to test the highest current level, as this headlight would draw 6A when tested which gives it a power draw of approximately 50W. I used a 12V 10W landscaping bulb in order to test the 5V system, and in this system this bulb draws 0.6A when tested, giving it a power draw is 3W. In order to test the lower voltage, the 3.3V at 1A I used another headlight bulb, this one rated at 12V 5W, it was outputting a power draw of 3.3A. This final bulb tested at 0.21A. The result of using a 12V bulb in both the 3.3V and 5V application is that the bulb does not reach its full luminosity. This can be seen as the lights are very dim, as shown in figures 9 and 10 below.

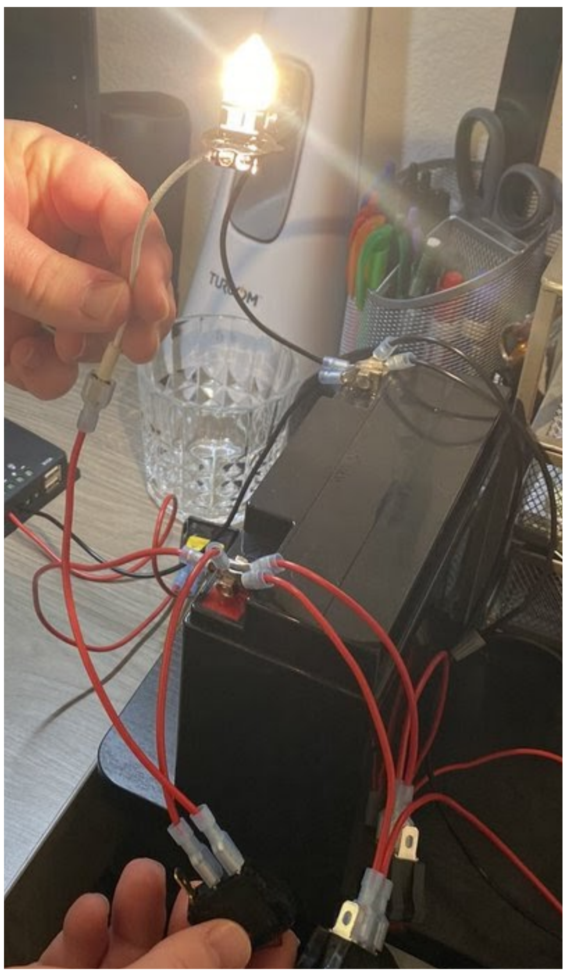

Figure 10: 12V 100W Light Bulb

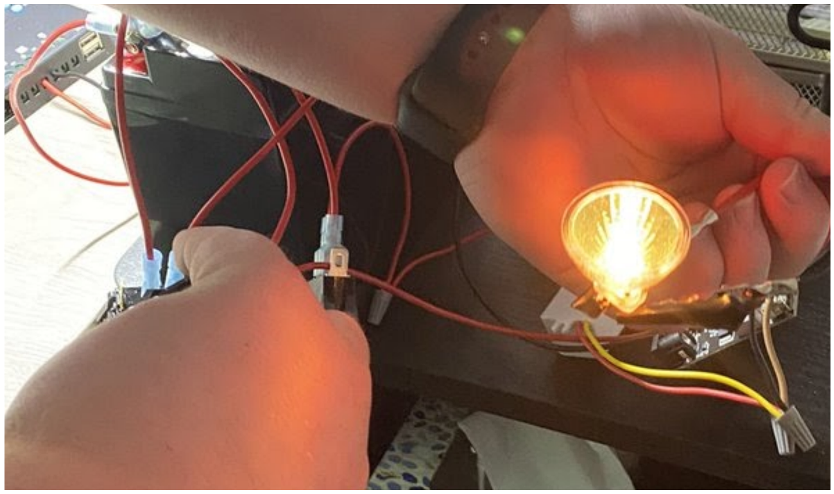

Figure 11: 12V 10W Light Bulb in 5V Circuit

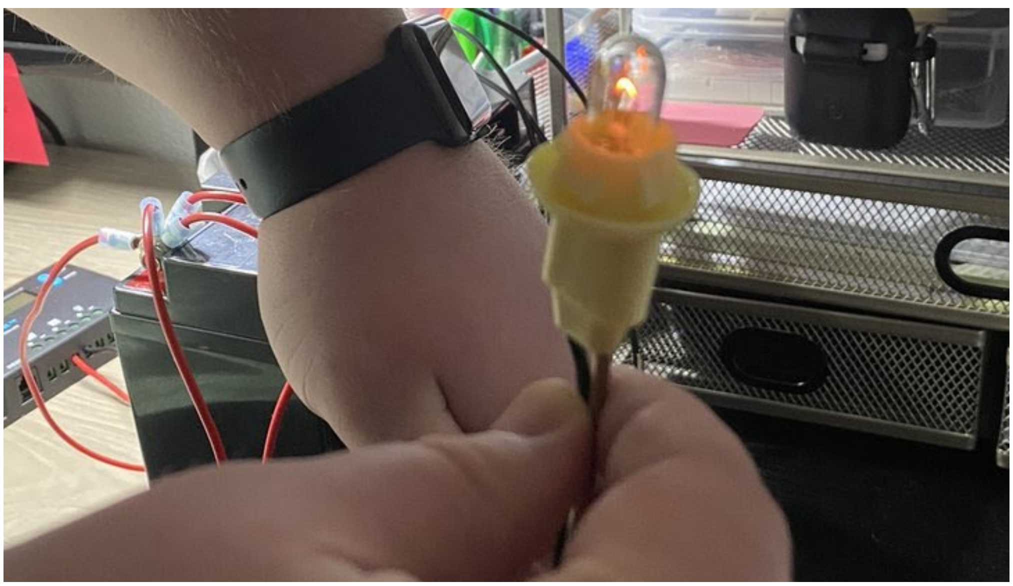

Figure 12: 12V 5W Light Bulb in 3.3V Circuit

5 Final Subsystem at the end of 403

Overall my subsystem consisted of quite a few parts that were obtained both from outside vendors, as well as from the lab room. In this section I will provide the size and weight specifications as well as a look at my assembled subsystem

5.1 Subsystem Weight at the end of 403

Component	Weight
Solar Panel	4.38 lbs
Solar Charge Controller	
Wall Plug	0.7 lbs
Battery	11.4 lbs
12V-5V Convertor	4.8 oz
12V-3.3V Convertor	30 g
12V 100W Light Bulb	0.05 lbs
12V 10W Light Bulb	0.03 lbs
12V 5W Light Bulb	0.02 lbs
Total:	16.946 lbs

Table 1: Autonomous Lawnmower Weight Specifications

5.2 Subsystem Dimensions at the end of 403

Component	Diameter	Length	Width	Height
Solar Panel	N/A	17 in	13.8 in	1.4 in
Solar Charge Controller	N/A	4.25 in	2.125 in	0.8 in
PCB (assembled)	N/A	4 in	6 in	0.7 in
Wall Plug	N/A	2.76 in	2.09 in	2.76 in
Battery	N/A	7.09 in	3.03 in	6.57 in
12V-5V Convertor	N/A	4.8 in	2.1 in	1.4 in
12V-3.3V Convertor	N/A	26 mm	36 mm	21 mm
12V 100W Light Bulb	0.45 in	0.71 in	N/A	N/A
12V 10W Light Bulb	1.375 in	1.625 in	N/A	N/A
12V 5W Light Bulb	N/A	3 in	1 in	4 in

Table 2: Autonomous Lawnmower Dimension Specifications

5.3 Subsystem Image at the end of 403

Below is an image that shows all of the components of my subsystem

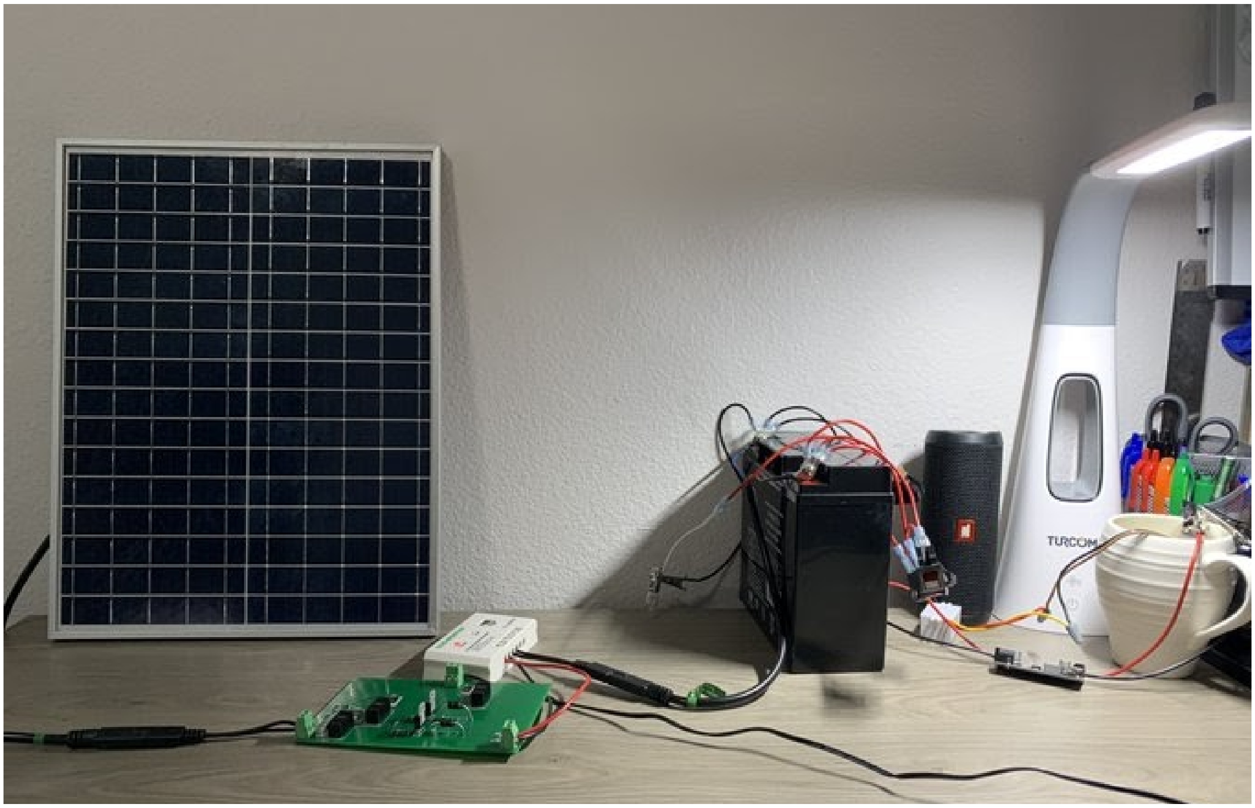

Figure 13: Power Supply Subsystem Overview Image

6 Component Mounting

The previous section outlined where the power supply subsystem stood at the end of 403. In this section, I will discuss the progress made throughout 404.

6.1 Internal Mounting

The first task of 404 in regards to the power supply was to find a solution on how to protect the electrical components from prolonged exposure to elements such as rain, dust, and sunlight. In order to do this I first acquired a plastic box within which the components were mounted. The PCB was mounted onto the inside of the plastic box, as shown in figure 12, using #8-32 1-¼ inch bolts and #8 nuts, a ¼ inch spacer was used in order to provide separation for the backends of the throughhole components. The solar charge controller was also mounted onto the inside of the plastic box, as shown in figure 13, using ½ inch #6-32 bolts and #6 nuts.

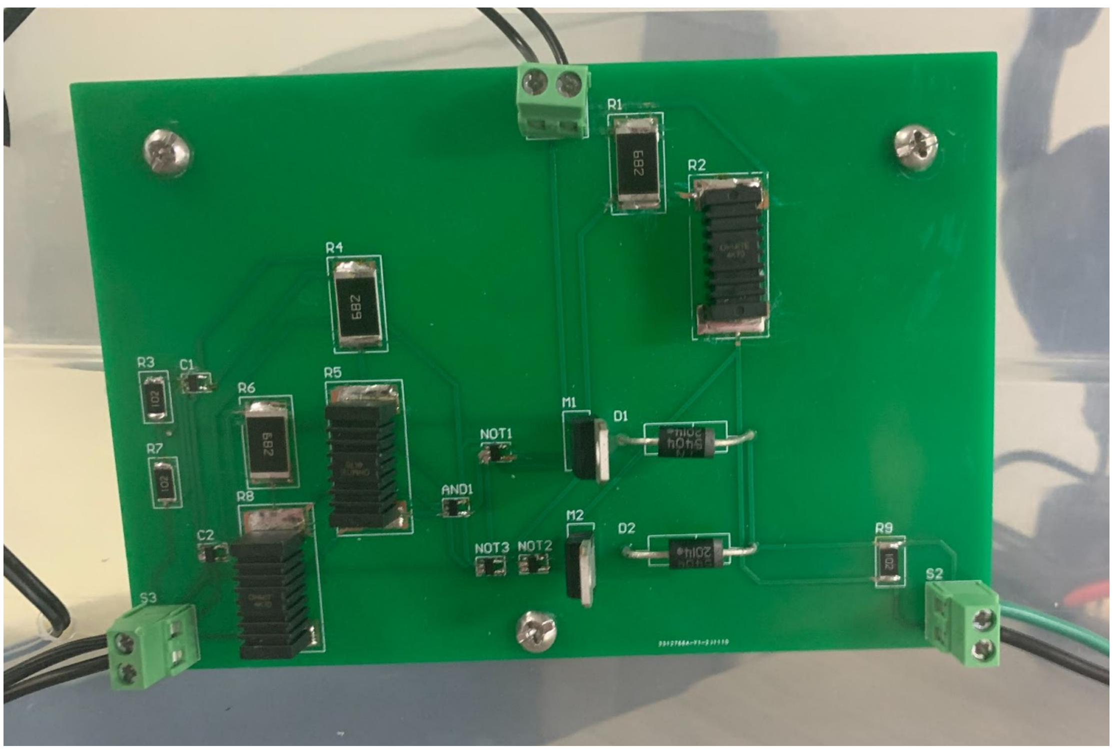

Figure 14: PCB Mounting Image

Figure 15: Solar Charge Controller Mounting Image

6.2 Wiring

In order to be able to power the electrical components mounted within the protective plastic box, wires had to be run through the box. These holes varied in size, with ¼ inch holes for the input of the wall plug and the output to the battery on the mower unit and a ½ inch by 1-¼ inch hole for the input of the solar panel.

6.3 Final Assembled Component Box

The box containing the electrical components mounted as explained in section 3.6.1 and wired as explained in section 3.6.2 can be seen in figures 14 and 15 below.

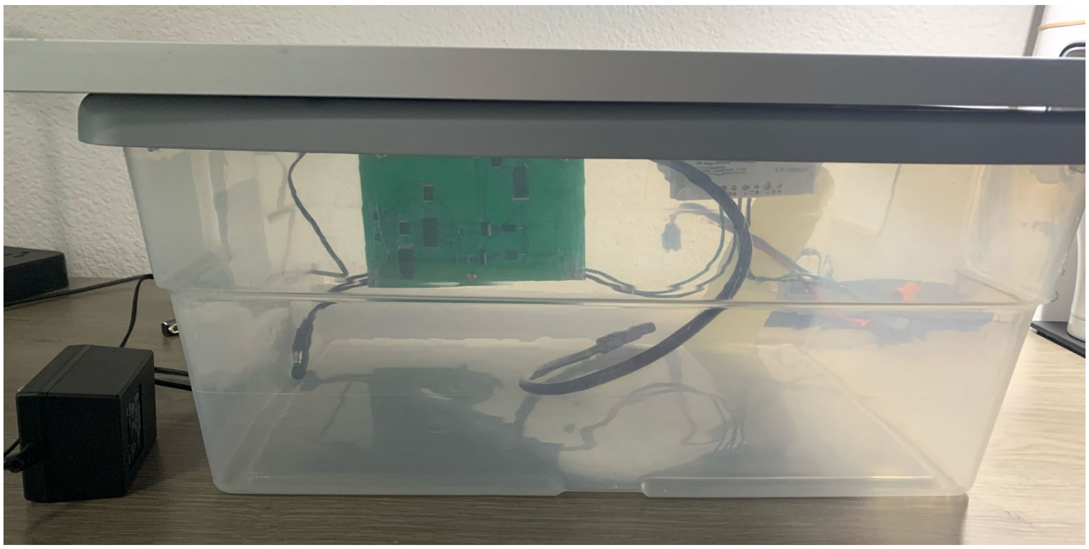

Figure 16: Power Supply Subsystem Overview Image from the side

Figure 17: Power Supply Subsystem Overview Image from the top

7 Unexpected Late Changes

Throughout the semester we encountered numerous issues with our motors subsystem. These changes, which included the installation of more powerful 250W motors and new more powerful 43A motor driver boards, are outlined in greater detail in section 4. To compensate for the new motors and now motor driver boards, we needed a more reliable power source than we could get from a sealed lead acid battery. This resulted in the acquisition of two 11.1V Lithium Polymer (LiPo) batteries. These batteries operated at 5Ah and 8Ah, respectively. In order to maximize the power into the new motors, we connected the two batteries such that we would have one 12V output and one 24V output. The 12V output powered the power block which was connected to the PIC32 microcontroller, the ESP32 microcontroller, the GPS, the gyroscope and accelerometer, and the blade motor. The blade motor remained the original 30W motor specified during 403.The 24V output powered only the new 250W motors and the new 43A driver boards. Figure 16 below shows the voltage output of the two LiPo batteries when connected and figure 17 shows the two batteries connected to the system through the 12V and 24V outputs. Also shown in figure 17, in the top is the makeshift bin (heb tupperware), which contains the 12 to 3.3V and 12 to 5V converters, as well as a bus bar to distribute the 3.3V and 5V power levels to multiple devices.

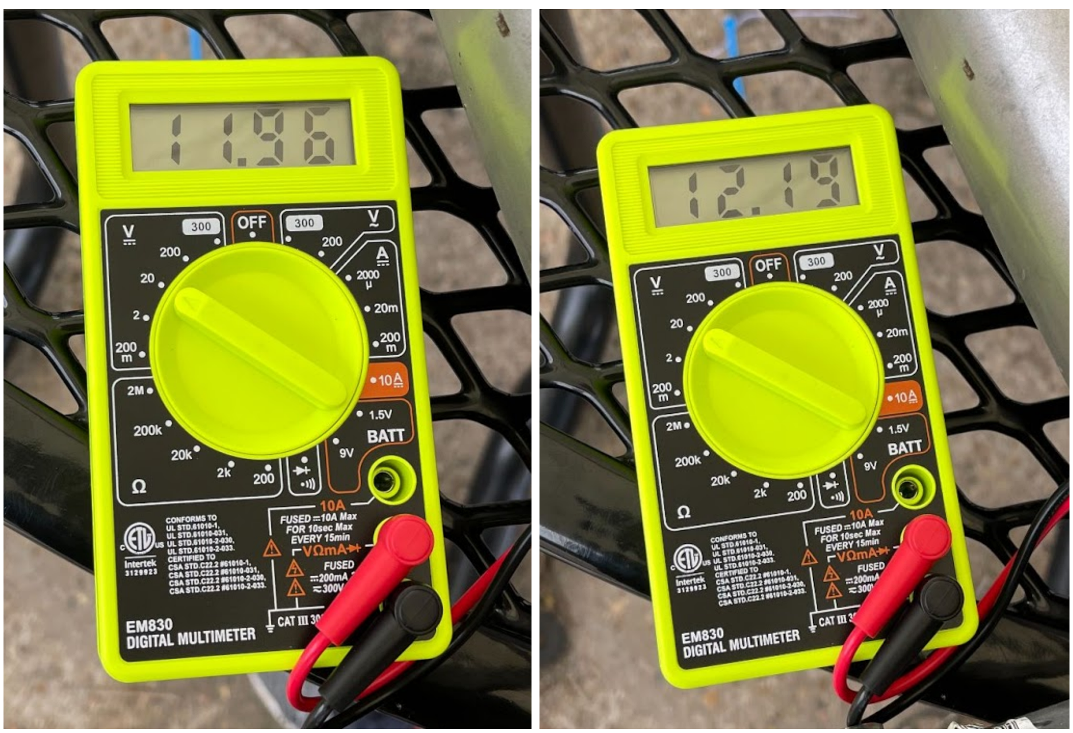

Figure 18: Voltage Output of New LiPo Batteries (5Ah - left, 8Ah - right)

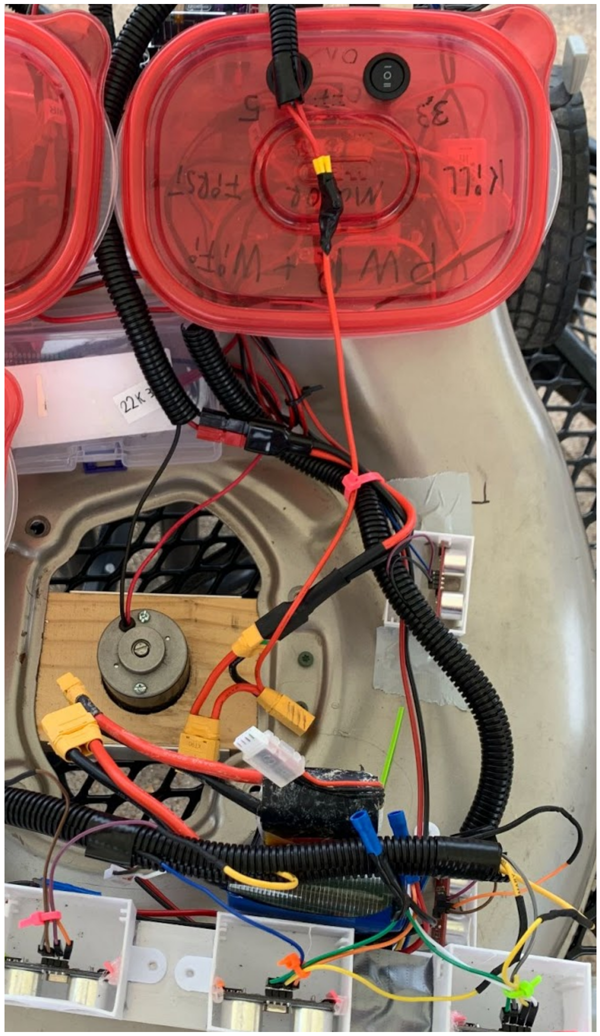

Figure 19: New LiPo Batteries Connected

8 Reflection

Back in August, when it was decided that we would be doing the autonomous lawnmower project, and then subsequently that I would be designing the power supply, I had very little idea about how to implement it. My first approach was to simply utilize a solar charge controller and panel that would have stayed on the mower at all times. After further discussion and research, it was determined that I would take two different power sources and utilizing a PCB determine which voltage source to use. In order to do this I would use a voltage comparator.

8.1 What I Learned

In August, I had never even heard of a PCB, much less Altium Designer. Through guidance from Professor Lusher as well as the resources of the world wide web, I was able to not only discover the endless possibilities presented by printed circuit boards, but I was also able to figure out how to use the software to implement them. Although this course does not use the entirety of the services Altium Designer has to offer, I was still intrigued to learn about things like the bill of materials, which are utilized in practical applications by numerous corporations. Another thing that is an afterthought to most when it comes to a physical project like the autonomous lawnmower is the action of connecting different components. Prior to this project I had never heard of a crimper, or attempted to interconnect electrical components using anything other than breadboard jumper wires. This course allowed me to get hands on experience in wiring and system integration that I would otherwise not have had.

8.2 What I Would Change If I Did It Again

Looking back now at the subsystem I designed, I believe that there are changes that could be made in order to improve the way I approached this problem. First, rather than trying to design the PCB to determine which voltage source to use like I did, I believe it would've been more beneficial to manufacture a single PCB that contained 12V to 3.3V and 12V to 5V convertors. By focusing on a single PCB by which I had two down convertors, I feel like I could've been much more efficient, as the process would have been more or less the same for each, just with different components. I also feel like this would have been a more practical application, as voltage convertors are used in everyday life, whether it be the plug you use to charge your iphone, or components within your iphone.