**Goals**

During my time on working on the Horn and Lights Project, HAL, I was able to manage and help guide new members in designing one of our application boards for Solar Car. HAL's focus is to take in data over our software's CAN network to turn on different lights and the horn in the car. If you have seen my writeup or video on buttonboard, you will notice that this is the direct inverse to that board, where this time we are receiving CAN packets and converting them to a voltage output on this board. Since the first revision of this board was already created in the previous year, it was our job to improve on where it had failed before. Specifically, we had issues with some parts being underspecced in how much current they should be capable of handling. Also, some of the traces on the PCB were not well equipped to handle current outputs over 5A. To fix this, we made our goal in redesigning the board to spec out larger parts, create wider PCB traces, and expand the board to 4 layers to make signal management cleaner.

**Design**

While looking at the schematic for HAL, you will notice that the power circuit is the exact same as buttonboard! Since the boards have similar functionality system wide, we made an effort to standardize our power circuit so if you work on multiple projects over the years, it’s easier to get in and implement them. If you would like to learn more about our power circuit, please watch my buttonboard video. The most important circuit of HAL is the MOSFET buffer, which uses 1 NMOS and 1 PMOS to buffer a 5V logic output signal from a microcontroller into a 12V power line that can be draw up to 10A. If we tried to draw that much current directly from the microcontroller, we would not have enough current to make the lights bright enough, and would also damage or kill the part. The first MOSFET is a NMOS which is smaller and does not need to handle as much current. This is because it takes the logic signal generated from the microcontroller on the gate of the NMOS and compares it to the source, which is connected to ground. If that signal is greater than around 2.5V, or our logic level high output of 5V, the first NMOS will conduct current from the drain to the source. When this happens, the gate of the larger MOSFET, the PMOS, will now be connected to ground. Since the current consumption of the gate of a MOSFET is practically 0A, we do not have to worry about the size of the NMOS. Once the gate of the PMOS is grounded, it will check the difference with the source, which is connected to our 12V line that also acts as an input to HAL. Since Vgs is less than around -6V, the MOSFET will conduct from the source to the drain. The drain of the PMOS is the 12V output which is then connected to a fuse in series and the output connector to the lights or horn. This circuit is repeated 8 times, each the same way for different lights or the horn output.

Even though there was a previous PCB designed for HAL, I decided that our team should restart from the ground up to both give us more room to piece parts together but also to give the new members on my team a better opportunity for hands on learning. Similar to buttonboard, we kept the power circuit on the left side of the board. Since we were using larger connectors for the 12V lights and horn outputs, we decided to keep the front side outputs on the top of the board and the rear side outputs of the car on the bottom of the board. As mentioned before, we also made the choice of making HAL a four-layer board. This gave us a plane for 5V, 12V, and two for ground. This made power management across the board much easier, since the buffer circuit needed both 12V and ground, while the microcontroller needed 5V across 6 pins. The four-layer board also made it easier to manage the control pins that turn the lights on and off since we were able to put them on their own layer and keep them cleaner. While the board ended up being much than its previous revision, it was now capable of handling any output that we needed from the solar car.

**What I Learned**

In this project, I gained both valuable experience a technical designer but also a manager. On the technical side, I was able to learn from the design mistakes we made last year and witness the effects of those first hand over summer testing. Through this work, we were able to make the team's life easier through systems implementation after the design cycle. As a manager, I learned how to be patient and encourage my teammates to try ideas out on their own. Most of the time I was around to suggest how to do something in Altium or answer questions, but the new members were the ones committing the design changes on the schematic and layout, which they did great in.

During FSGP 2022, we had a great opportunity of seeing this work pay off. After using the horn so often while passing other solar cars, it started to sputter and eventually break during out last day on the track. We had to have an emergency swap of a new horn that we bought at an auto store, and we were prepared to swap it in the car because we knew that the new version of HAL was capable of outputting that much current. Since things were so hectic, we didn't have the time or equipment to measure the current draw of the horn, and were able to swap it in. Seeing these impacts right away are always very satisfying to me, since I am able to see the time and work pay off in a very fast paced situation at race.