Adventures in Avionics - A Summary of Accomplishments

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This semester, I had the pleasure of being a part of the IREC team for my Junior Engineering Clinic project. Boasting fifteen student members, a student clinic consultant, and a faculty advisor, the team was one of the largest of the clinic groups. In terms of teams tasked with building a rocket from scratch, sixteen students is not a lot. There was much to be done for each of us.

The first meeting of the semester went like most first meetings do. Everyone introduced themselves, and once everyone had a feel for what each of the sub-teams do, each of us selected a team to be a part of. Since I enjoy designing and testing electronics, the avionics sub-team felt like a good fit for me right off the bat. In subsequent meetings, I would find out that I made the right choice.

In the first *real* meeting of the semester, we started our engineering design process by defining the requirements and constraints for the rocket. In the year prior, the avionics sub-assembly was located in the nose cone due to radio communications constraints. This year, we wanted to put avionics in the body tubes to simplify the wiring of the rocket. To be able to do this, we had to change the body tube construction from carbon fiber to fiberglass. Avionics was also constrained by size and weight. Since the sub-assembly was to be located in a body tube, we were constrained by the size of the body tube. We also determined that it would be a good idea to keep the sub-assembly under five or so pounds, although this was more of a goal than a constraint.

In the second week, I sorted through the avionics supplies and helped put together a cumulative inventory spreadsheet. This involved setting aside unused, broken, and waste components, and sorting through miscellaneous radio and flight equipment.

Once our closet was organized, avionics was able to get to work. We found that some of our flight computers needed repair. One was missing an SMA connector for its antenna, and another one was missing the solder pads for mounting an SMA connector. I was able to repair the one with the missing connector, but the one with missing pads would have to be put on the backburner.

Over the next several weeks, I helped test radio communications with our largest and most powerful flight computer. This was done since this computer was likely to be at the heart of the primary avionics system. Due to budgeting constraints, we planned to use a much smaller and less powerful flight computer to power the backup system.

At this point, we were making assumptions based on the rules from the previous year, but in early October, the rules for this year were published. One of the major changes had to do with the types of batteries permitted. In years past, the flight computer was powered by a 3.7 volt lithium polymer battery. This year, lithium polymer batteries were heavily restricted due to fire hazards. A workaround would be required, and I stepped up to the task of power management.

Starting in week five, I began developing the power supply system for avionics. This power supply would require two output voltages: a 3.7 volt rail for the flight computer and a 12 volt rail for the separation valves. I came up with four possible topologies to start. In the final design, I ended up abandoning all of my initial ideas.

From week five until the end of the semester, I designed and iterated on the power supply. First I made one using two bipolar junction transistors, a resistor, and a Zener diode. Although it was a simple design, it used a lot of power. Our batteries had to last at least three hours to be able to maintain radio communications to recover the rocket. Using a power hungry power supply would eat through our power storage, so alternatives would have to be researched and developed.

For several weeks, I experimented with using a 555 timer with a set duty cycle to control the output voltage of a buck converter. Unfortunately, the 555 timer required its own power supply, and the output voltage would change based on the load.

Once the valve we were using came in the mail, we were able to perform some tests on it. Despite being rated for 12 volts, our initial tests showed it only needed about 3.1 to 3.3 volts to work properly.

We performed more tests with an air compressor hooked up to the valve, and found that as pressure increased, so did the required voltage to open it. At the pressure that would be used in the rocket, the minimum voltage had increased, but it was nowhere near the 12 volts that we had initially expected.

Knowing this, we determined that a 9 volt battery would be more than enough to power the valves. Before these tests, we were planning regulating a 20 volt electric drill driver battery down to 12 and 3.7 volts. Switching to a 9 volt battery significantly simplified the design.

With a 9 volt battery, the 555 timer no longer needed its own power supply. Now it could be powered directly by the battery. However, the output voltage of the power supply still depended on the load. To mitigate this, I started experimenting with a feedback mechanism.

I planned to measure the output voltage with an op amp, and then use a JFET as a voltage controlled resistor to change the duty cycle of the 555 timer. Suffice it to say, I just couldn't get it to work.

During the last meeting of the semester, I had an epiphany: instead of using a 555 timer to control the MOSFET in the buck converter, I would use a new feedback mechanism to directly control the MOSFET. In simulations, this design worked wonderfully. The power supply used very little power, and had a stable output voltage under a varying load. Additionally, this design was one of the simplest that I had come up with.

I learned a lot about electronics this semester, and I cannot wait to continue working with IREC next semester. Beyond electronics, I learned more about working in a group with a common goal, and I learned the importance of iteration in the engineering design process. Next semester I plan to implement my power supply on a breadboard and the entire avionics sub-assembly on a printed circuit board. Despite being one of the larger clinic teams, I certainly had my work cut out for me.