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ECE 118: Introduction to Mechatronics

26 April, 2024

Lab 2 - Mechanical Prototyping

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Introduction

In this lab we built a prototype robot housing out of MDf and foam core. We learned how to use Solidworks in order to design our prototype, created 3D models, and layed out the pieces onto a drawing in order to print them out with the laser cutter. We also learned how to use the laser cutter for the first time. Additionally, we redesigned our beacon detector from lab 1 and resoldered it onto a perfboard with the addition of a regulator and power connector.

Part 1 - A Simple Gearbox

In part 1 of this assignment we were tasked with creating a gearbox to house the parts of a gear system. This would give us practice for part 2 in which we would be designing a moving platform and motor mounts. We based our design of the box purely on the provided drawings and made note of important measurements and cuts so we could get the tab in slot connections correct. We started by making the bottom piece and side pieces. We designed by creating rectangles and making extruded cuts. In order to make the side pieces, we had to cut holes and bottom slots that matched the width of the bottom piece. This bottom piece gave us the most difficulty as it would clip into the sidewall or leave a gap when resizing the material. This turned out to be an issue with one of the dimensions of the bottom piece being incorrect. We fixed this by making sure the right areas adjusted to the material thickness and changed how they should. This took a bit of trial and error. We also had to modify the provided gear template files in order to create the gears seen in figure 1. To do this we had to change the equations of the templates individually. Assembling the box and making mates was a little challenging at first--we would get weird connections and overlaps. However once we solidified our understanding of how mates connect where and how to properly secure, we were able to assemble the box with relative ease.

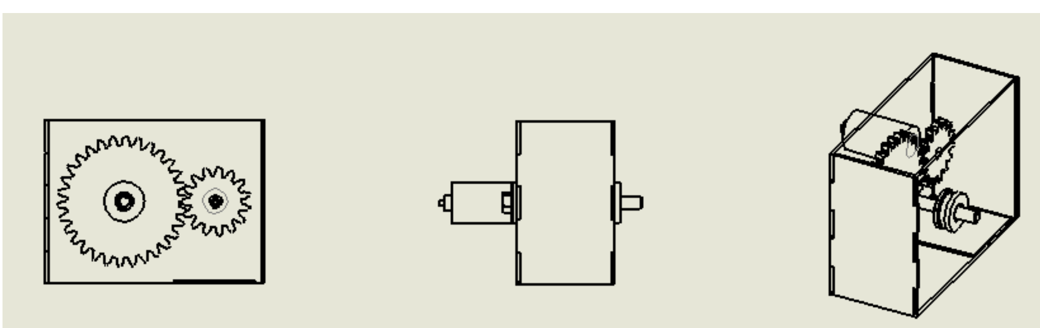

Fig 1 | Three perspectives of the gearbox

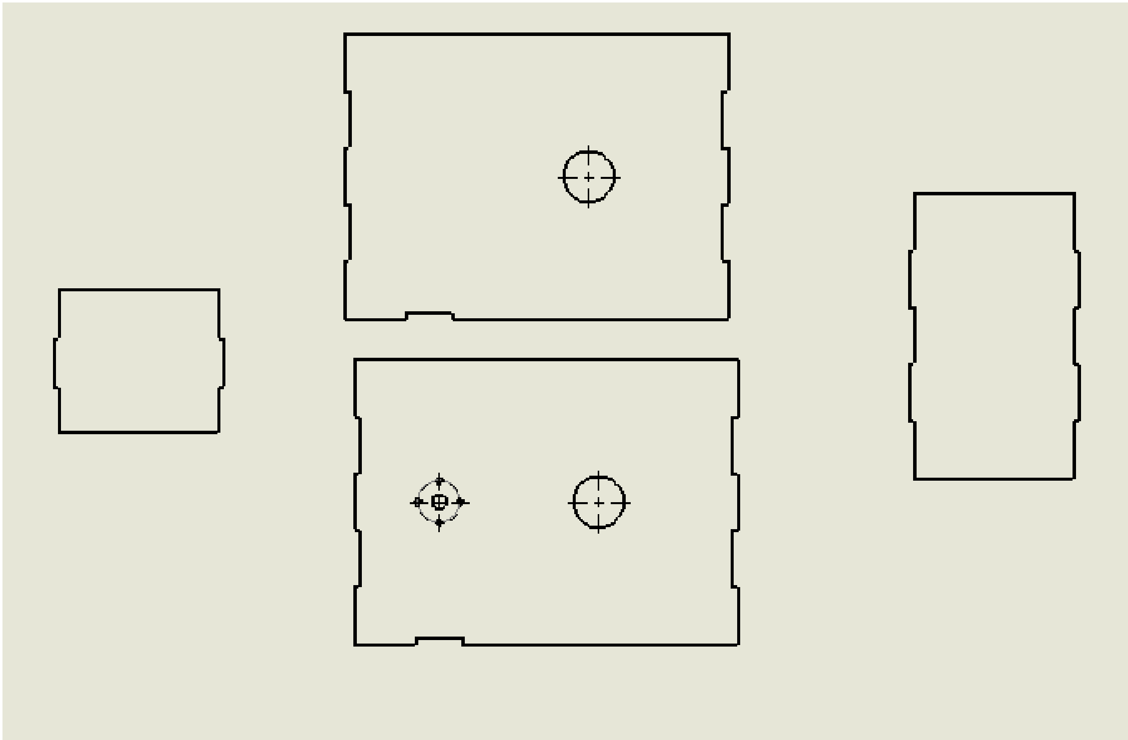

Fig 2 | The cutout drawing for all the gearbox pieces for printing

Part 2 - Designing a Motorized Platform

Our design consists of two lower housed motor mounts, an octagonal base, and a cylindrical tower with a box on top. We wanted to keep the design simple and easy to cut so as to save time on the laser cutter for later. This would also help us as a complicated solidworks design would take too much time and make us confused. Initially our motor mounts were above ground on the platform. We decided to put the motor mounts below the main platform so that the wheels would not be offset as high as they would be if the mounts were above the platform. It was also important to be able to remove the motors which would be impossible if they were housed on top once the tower was in place. We decided to make the main base in an octagonal shape so as to limit the amount of surface area and save space on the MDF piece. We also put the holes for the H bridge module on the side, measuring the holes precisely, and having it close enough to the motors to connect.

A challenge of this part of the lab that we were not expecting was the math and relations behind creating all of our boxes and designs. A lot of the time we had to go back and make small adjustments to our motor mounts because we forgot to account for the height of the lip, the height of the wheel, etc. Having global variables was very helpful in keeping the sizing and tabs and slots aligned, however it also took us a while to understand how to properly set up the file with the global variables without getting errors. Our final design and drawing perspectives can be seen in the figures on the following pages.

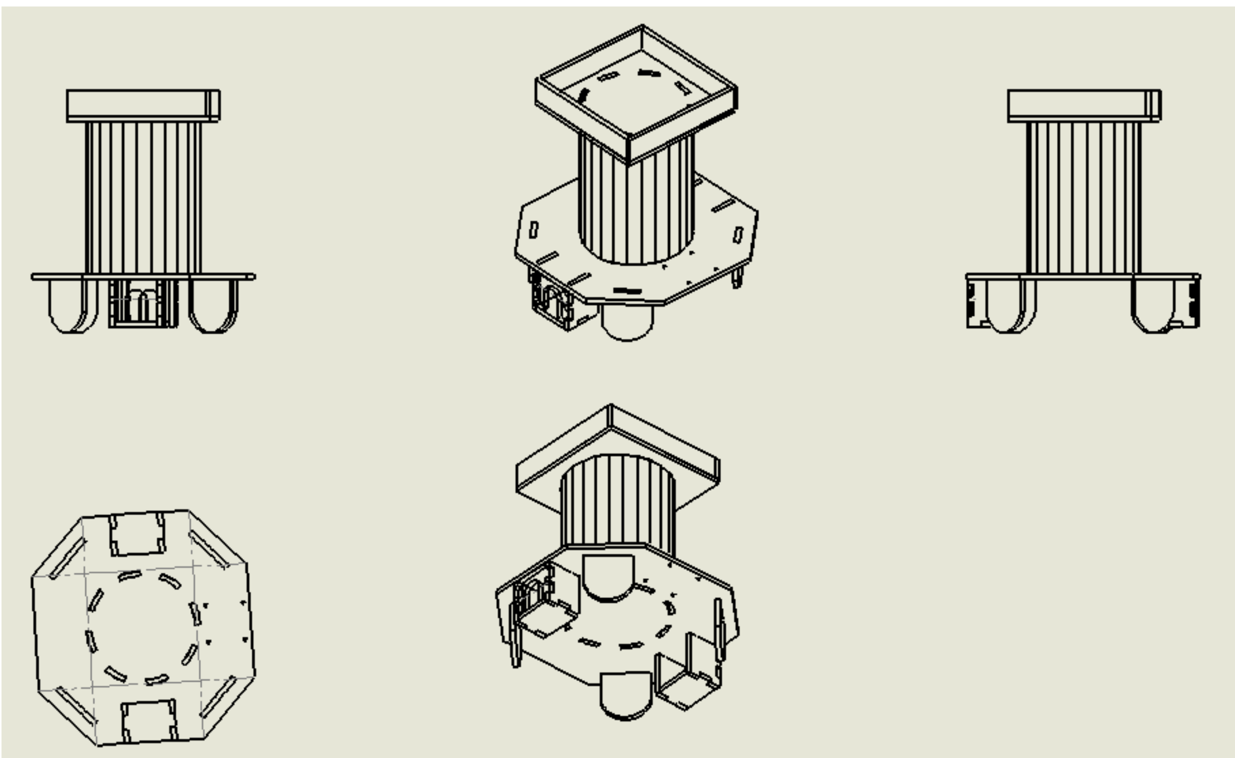

Fig 5 | Multi Perspective Drawing View

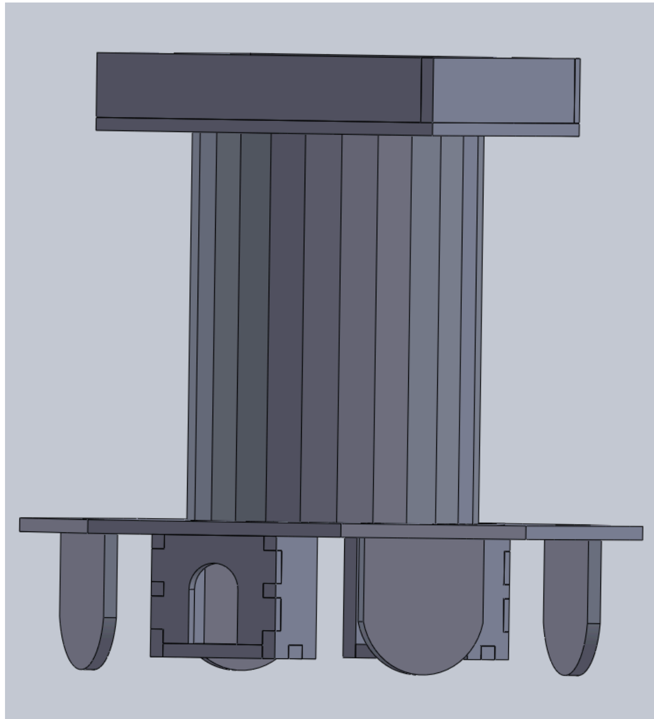

Fig 6 | Front view of full moving platform

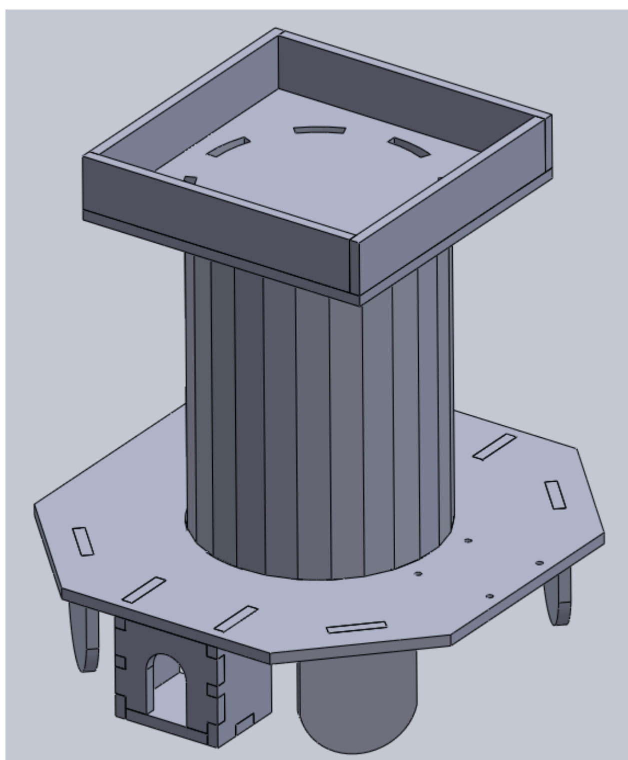

Fig 7 | Side view of full moving platform

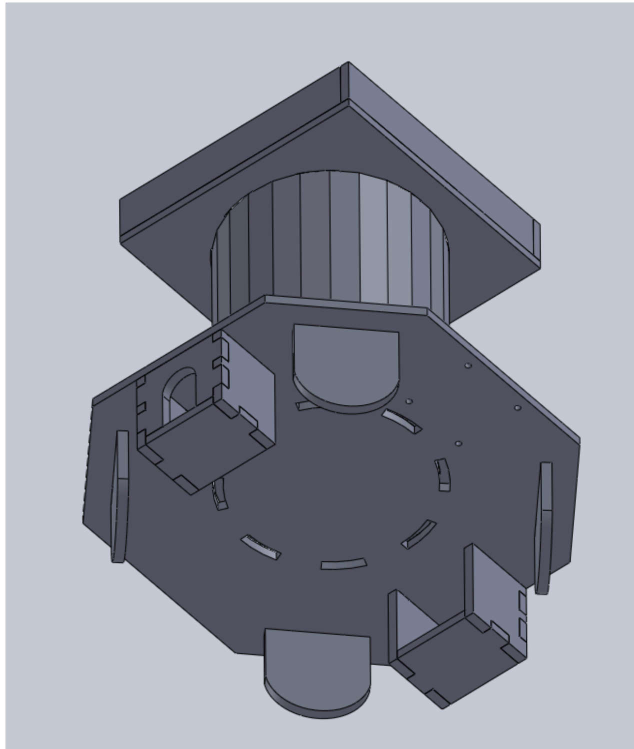

Fig 8 | Underneath view of full moving platform

Part 3 - Prototyping The Motorized Platform

The final designs are seen in figures 9 and 10. Construction began by cutting out the pieces we designed in part 2 onto the MDf using the laser cutter. In order to make the center cylindrical tower, we cut 27 1 inch wide strips. This allowed for the foamcore to be bent into the desired shape. We had to cut many of the ends short in order to create the tab in slot connections to the main platform. The box itself was also cut out of foam core with dimensions of 5.5 inches by 5.5 inches by 1 inch.

When we were assembling the design, we ran into some difficulties with the motor mounts and wheels. The fit of the motor mount was a bit too snug due to using different motor parts when designing the boxes. The boxes themselves assembled together just fine, but some of the tab in slot connections were a little looser than we would have liked. This was likely due to the MDF value in our global file being slightly larger than it should have been, likely by 0.01 inches or so. However, with the hot glue we were able to make the connections secure. The glue also added just enough height and width so that the motor would fit without a struggle.

In retrospect it would have been good to make the wheel slightly bigger. This would give our platform more clearance and make the platform easier to drive. Alternatively, we could have made the skids a bit smaller as well, though we liked how their size kept the platform from falling over. Accounting better for the wires from the motors as well as the clearance space for the motors would improve the design.

Fig 9 | Side view of full assembly

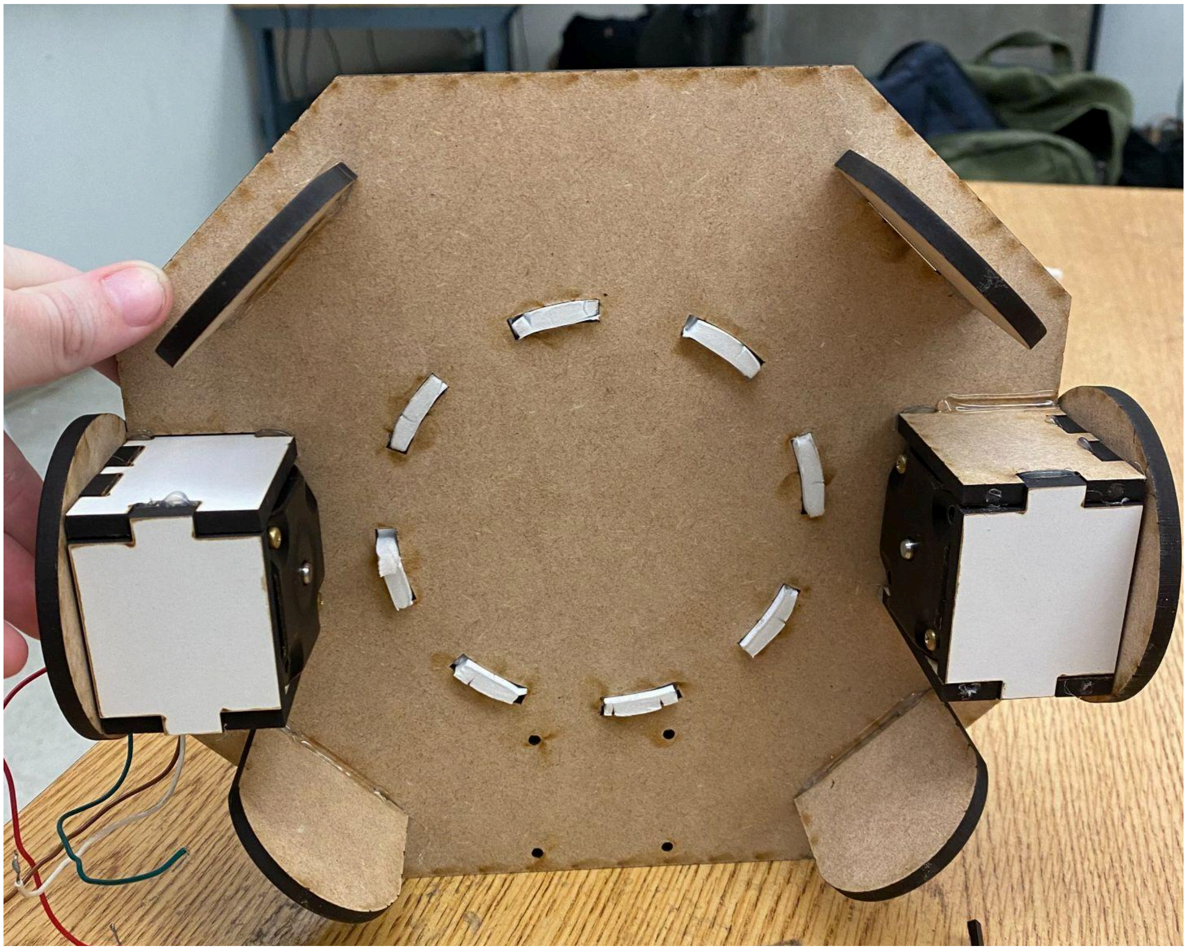

Fig 10 | Underneath view of full assembly

Part 4 - Beacon Detector on Perfboard

When we first tried assembling this project, we ran into a lot of issues. The main issue, we later learned, was with our filter. Both of the filters we designed initially in lab 1 did not attenuate enough when off of the breadboard. This meant that the voltage of the 2kHz signal from 6 feet was the same as when the 1.5kHz from 1 foot. This meant no matter how much we amplified the signal, the two cases would be indistinguishable and our design would not work. After spending many hours debugging and resoldering, and coming to the above conclusion, we decided it would be best to start from scratch.

With a new design in mind, we started planning how to organize the perfboard to maximize space and usage of the op-amps in the chips. We tried to use as few op amps as possible while leaving enough space for all the components and connections. For the first few iterations we had started with building the circuit block by block in order. This time we started with the filter as it had given us the most issues. We also implemented the circuit with 3.3 V as the input since we could easily integrate the voltage regulator once we had verified we had a working circuit. Initially we implemented a split rail buffer as we would need it for the virtual ground connections in our bandpass filter. Once we verified the split rail was outputting 1.65 V we were ready to move on.

We built the bandpass filter in stages, verifying with a signal generator that the values were what we expected. To filter out signals other than 2 kHz, we used a 4th order butterworth bandpass filter. This way we combined both the high and low stages into 1 filter. We had to go with a completely new design due to the issues previously described. We decided to make the bandpass much tighter than our previous 200Hz in the hopes this would fix our issues. The texas instrument filter design feature, was able to provide the new values for our filter as specified in the schematic in figure 11. It is believed a lot of the issues we were having before were due to the design working exclusively on the breadboard due to the internal resistance, which does not translate when working on the perfboard. Previously we had to rewire and re-solder a circuit on the perf board quite a few times, which took a lot of time and created a lot of frustration. As this had been the hardest part, we made sure that the signals around 1.8 kHz and 2.2 kHz attenuated enough.

Once we had verified that our filter worked well, we implemented the transresistive amplifier and tested it individually. As expected it outputs a small sinusoidal signal when receiving a signal from the 2kHz pucks. We used a 1k ohm feedback resistor to linearize the output, and connected the input to our temporary 3.3 V power supply. Since the voltage signal was so small, we moved on to implement an amplification stage. Previously we had done two separate amplification stages which were amplifying the AC bias, and causing us to get unexpected results. For this new redesigned amplification stage, we implemented one stage, a non-inverting amplifier with a gain of about 19. This was also tested independently with a signal generator. Once we verified that it was amplifying as expected, we moved on to connect the transresistive amplifier output to the amplification. After testing with multiple oscilloscopes, we saw that the initial signal from the phototransistor was amplifying to a large degree.

Now that we had an amplified signal, we passed this to our improved bandpass filter. The filter let in 2kHz while filtering out 1.5 kHz and 2.5kHz from the pucks. Once we verified that the filter did attenuate signals other than 2 kHz we started implementing the remaining stages of the circuit. Since the filter attenuated the undesired frequencies from 6ft we decided not to implement an amplification stage as we had done in previous iterations.

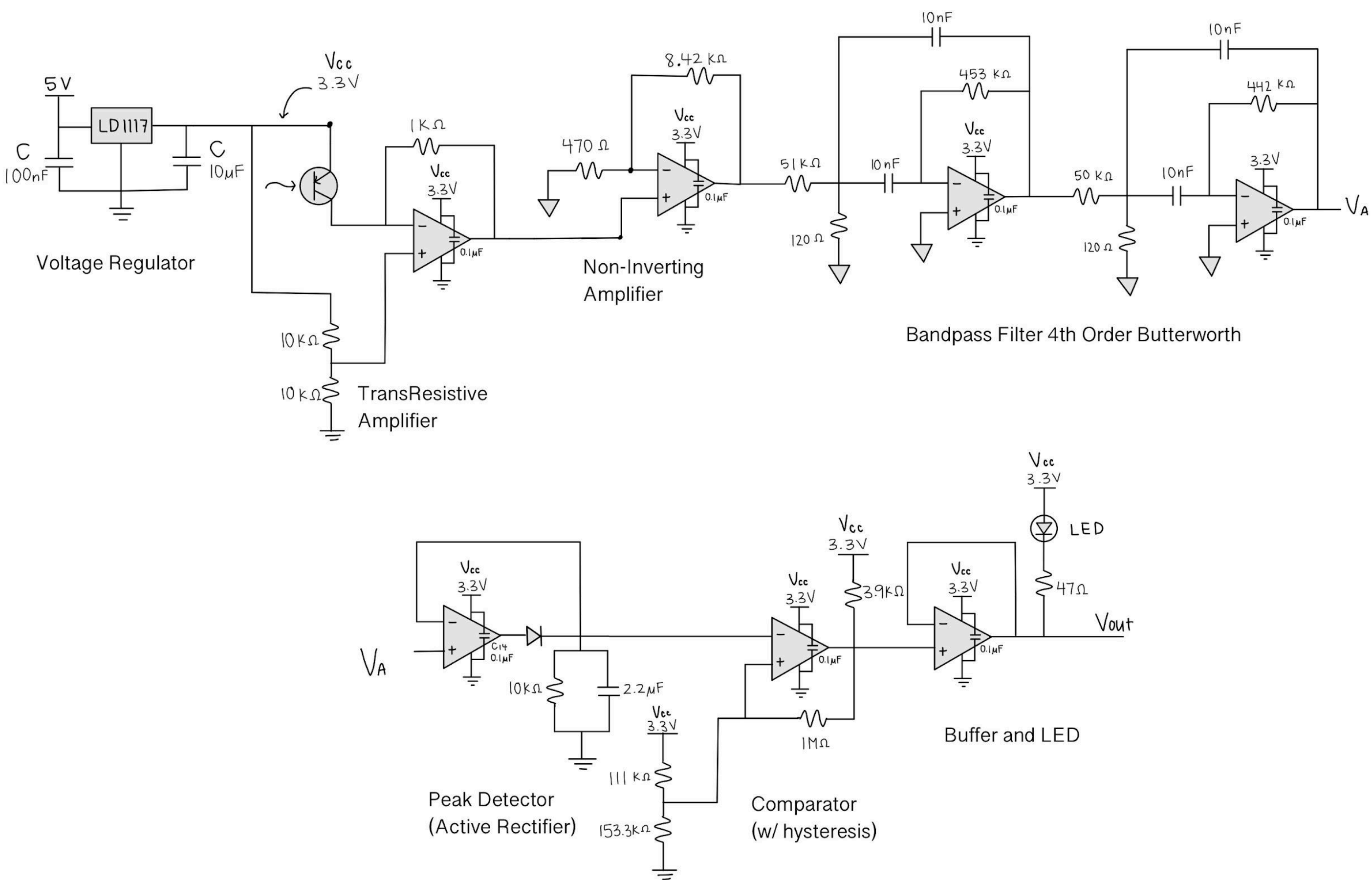

Fig 11 | Full beacon detector schematic with LED output

The next stage was the peak detector, which will be used to hold the peak of the signal high around its max voltage and slowly attenuate the signal. However, due to the RC time constant we set, which was 20ms, the signal barely attenuates. This is because the time constant has an inverse proportionality to the frequency, and the high time constant means the frequency is lower than the frequency of the beacon so it does not have time to attenuate. Just as with previous stages we tested the peak detector independently using a signal generator to make sure the signal would not attenuate. Once this was verified we connected the output of our bandpass glitter to the input of the peak detector. After verifying that it worked in our circuit when receiving signals from the puck we moved on to the next stage.

The output of the peak detector when a 2 kHz signal is detected was used to set the thresholds for the comparator. The comparator will compare the output voltage from the peak detector and if this voltage exceeds the threshold, the comparator will output a high voltage. This binary output will be used in the next stage to light and LED but will also become the output as a digital signal.

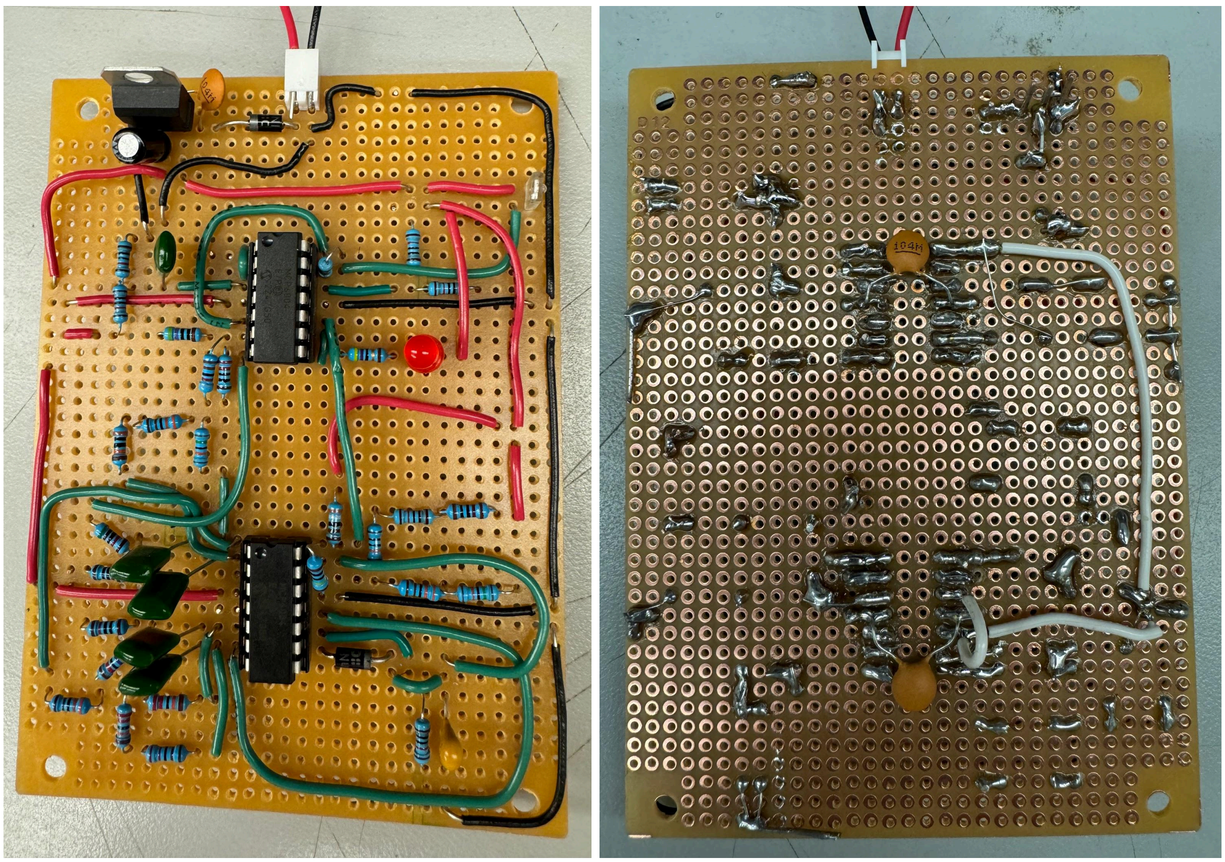

Fig 12 | Front and back of the soldered beacon detector

The current circuit we have can be seen in Fig. 12. It is the final improved circuit that implements the transresistive amplifier, one amplification stage, the filtering stage, peak detection, a comparator stage with hysteresis and a buffer and LED.

Conclusion

We learned a lot of new skills in this lab. Both of us gained understanding and confidence in Solidworks. We also learned a lot about proper soldering techniques and circuit design by building on the perfboard. Additionally, we spent a lot of time redesigning and debugging our circuits due to errors with our bandpass filters and amplifiers. Through these challenges, we became better electrical engineers and solidified our circuit design skills. If we were to redo this lab, we would have started the soldering process sooner and would have not soldered sequentially like we did initially. We would have started with the most important parts first rather than going in order. This would have saved us a lot of time. Despite this, we were able to get the beacon detector to register at 2kHz beyond 6 feet and signal out anything else at close and long ranges. Overall, we are happy with the results of all of the parts of our lab.