Lab 2 Lab Report - Mechanical Prototyping

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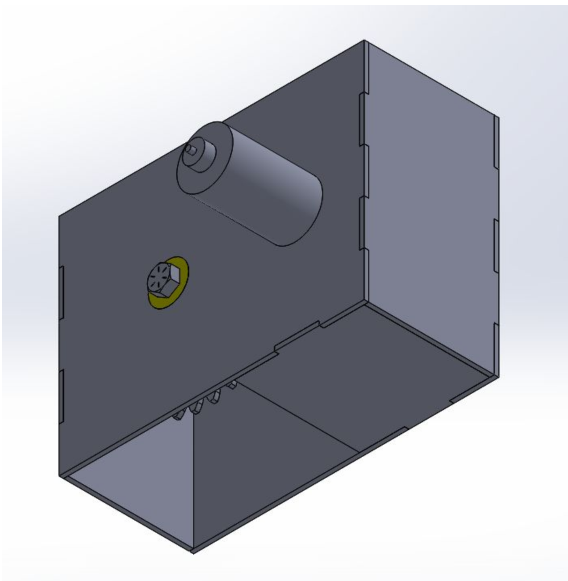
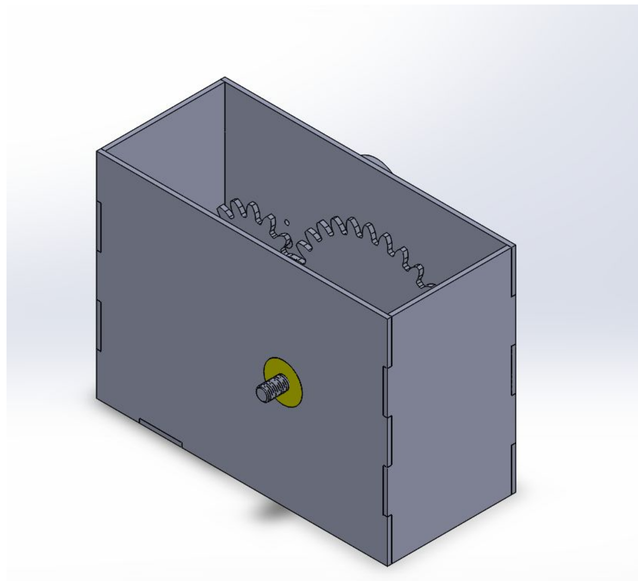
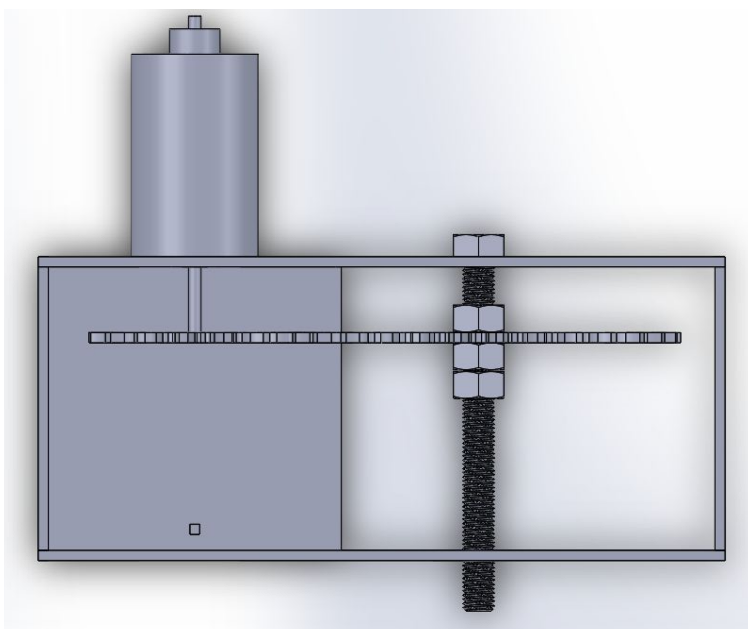
Part 1 - A Simple Gearbox

Part 1 requires the complete 3D modeling of a gearbox assembly in SolidWorks based on the provided dimensional drawing. The emphasis behind this part is to familiarize the modeler with global variables/equations, tab and slot construction, and various mating techniques.







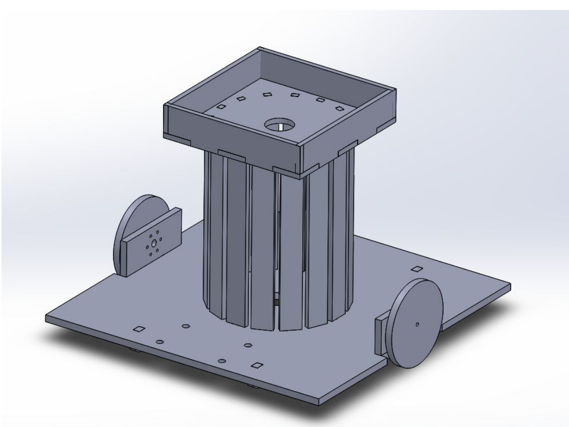
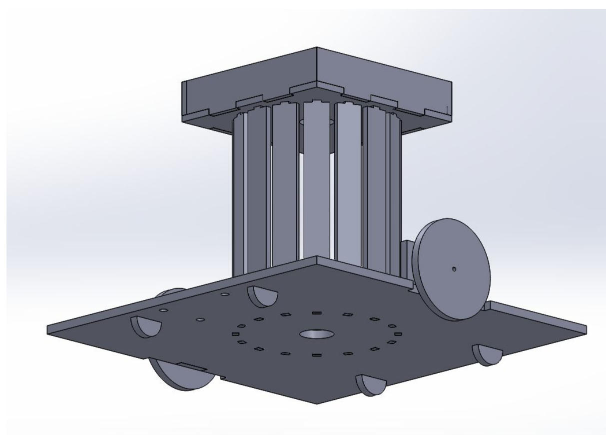
I began construction of the gear box by creating the outside walls. The height and length as specified in the schematic and the material thickness as a global variable. The slot and tabs were then cut out between the four walls. This was accomplished easily through the techniques learned in part 0 of this lab. The holes for the gear and motors were then cut into the front and rear side of the gearbox. Followed by the screw holes for the motors. This was accomplished by creating one hole and using the circular pattern tool to create the other three. PRoper bolts, nuts and bearings were found on McMasterCarr and placed into the assembly. Lastly the gears were edited to hold the correct pitch and tooth count, given the ability to change thickness with the global thickness variable, and imported into the final assembly. Each part in the assembly was mated to those adjacent to it. In doing this, the spatial relationships will be preserved even when the material thickness variable is changed.

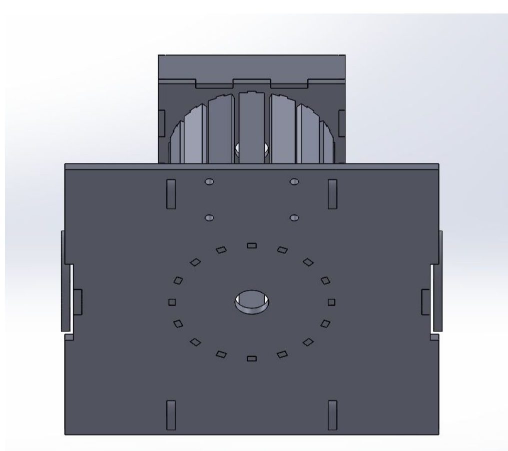
Following the proper creation of the gear box, the assembly must be laid out flat, imported into a 20”x30” drawing at a 1:1 scale, and exported as a DFX file. The final product is shown in the image below. If we were laser cutting this assembly this file would be imported onto the laser cutter.

Initially I had difficulties creating the tab and slot design due to the overlap of the walls. My walls were overlapping because the tutorial has this as the proper setup for tab and slot. In order to get around this I created each wall and their corresponding tab and slot before moving onto the next. Thus ensuring the correct wall received the proper tab or slot configuration. Once past this portion, the proper mating and scaling with use of a global variable was fairly simple.

Part 2 - Design a Motorized Platform

This design features an 11” x 11” MDF base. 4 MDF Skids on the bottom of the base to assist the base in not dragging during movement. The h-bridge is mounted in the rear to assist with keeping the roach stable and balanced on the 2 wheels and the 2 rear skid. The h-bridge also has a clear path to the motors on either side. Ensuring ease and secure connection to the motors. The two motors and 76mm MDF wheels are mounted on the centerline of the base. This ensures the tightest turn radius possible and in turn maximizing mobility of the motorized platform. The 6 screw MDF motor mounts secure the motor to the base of the platform, but allow for easy removal when necessary. The cylinder is comprised of 16 foamcore pillars locked into place through tab and slot construction on both the base and tower box. The pillars are evenly spaced over the 4.5”diameter circle and are 6” tall. This construction allows for maximum stability for the tower box.The tower box on top of the pillars is also made out of foamcore. The box is a square with a side length 5.5” and a depth of 1”.

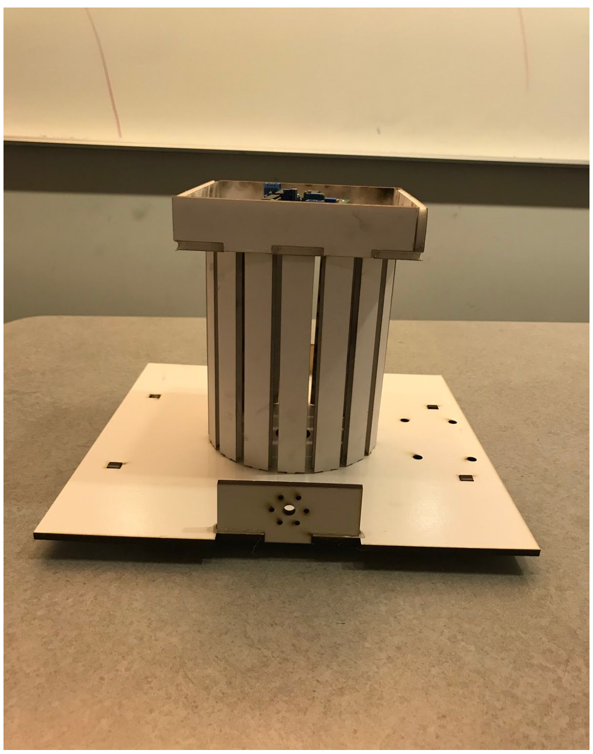





The only hurdle we faced during this part was importing a DFX file into the laser cutter program. The laser cutter program would greatly expand our drawing. We are unsure of the causation of this problem because the dimensions are correct on the DFX file. The solution was rescaling the drawing on the laser cutter program. This is made simple using the grid pattern on the cuttable area in the program along with the measurements along the top and side of the program.

Part 3

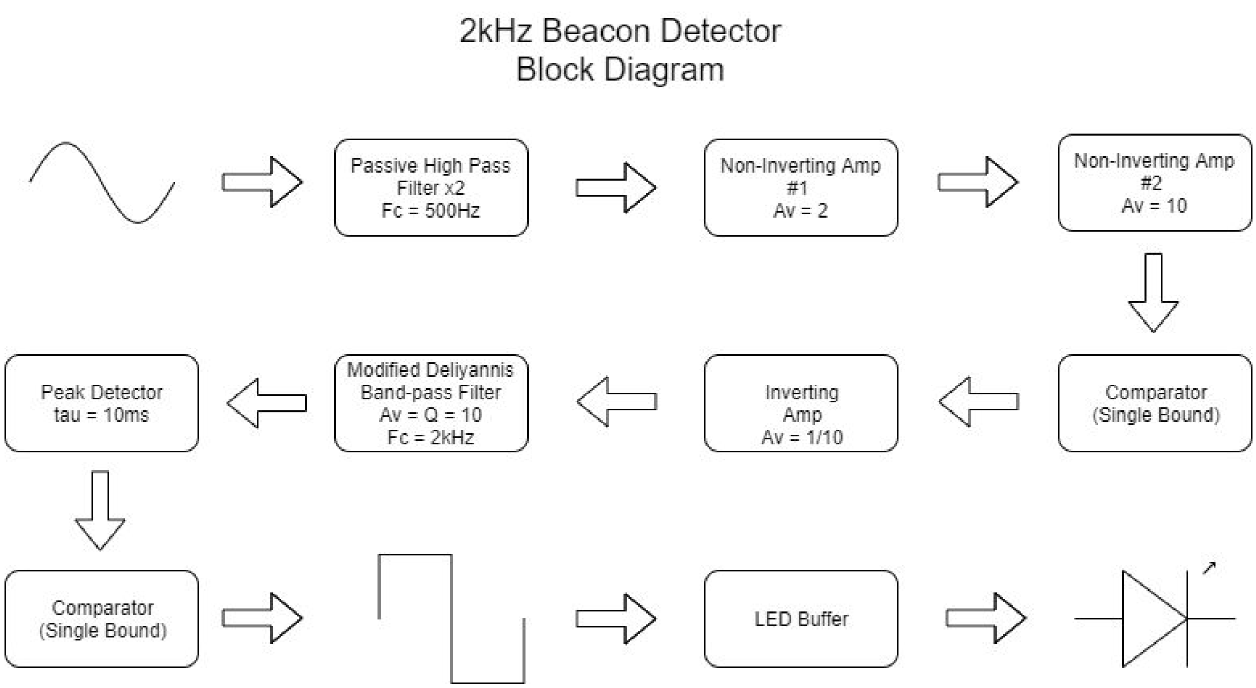
In part 3 we took our designs from part 2 and brought them into the real world. We spent most of our time in this part dealing with the logistics of laser cutting and gathering materials to build the base, motor mounts, and tower. Since we were the first group to laser cut there was some confusion and we were allowed to laser cut both our MDF and foam core. Because of this, our finished design looks very sleek and clean and we got checked off even though we didn't hand cut the foam core.



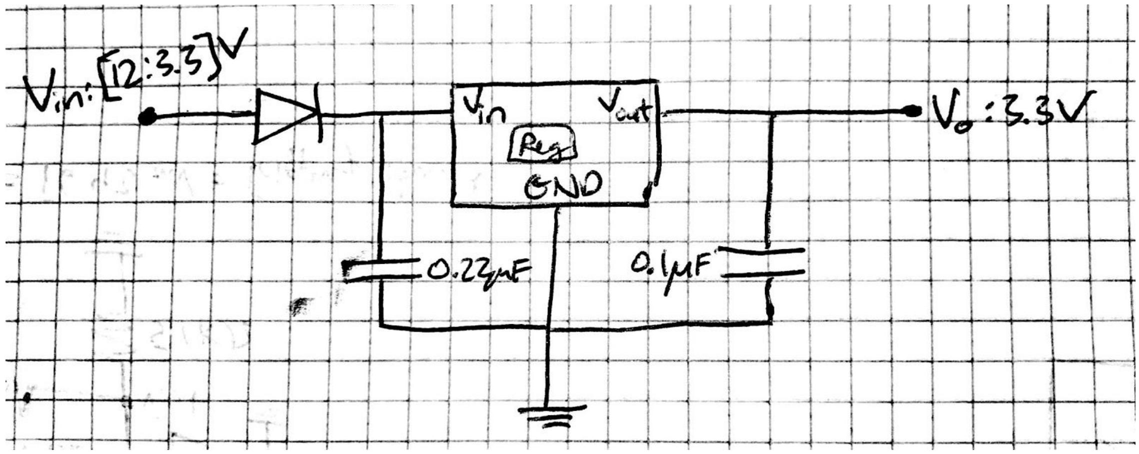

The actual cutting and assembly of the parts were pretty straightforward and easy and didn't take too much time. The main challenges we faced were the result of laser cutting the foam core. The main problem was that while cutting the foam core we set the speed of the laser cutter a bit to slow. This caused the edge of the foam core to melt and bit which slightly compromised the strength of the pieces, mostly at the tab and slot connection points. To counter this problem we made sure to load up the tab and slot connections with amble hot glue which filled in all the gaps and resulted in a pretty strong design. The other problem caused by the slow laser cut was slight burning which occurred on the backside of the foam core. We made sure to hide these pieces as best as possible although you can slightly see them in the top of the tower. All in all we were happy with the mechanical strength of the finished designed as well as the clean and sleek look we achieved.

Part 4

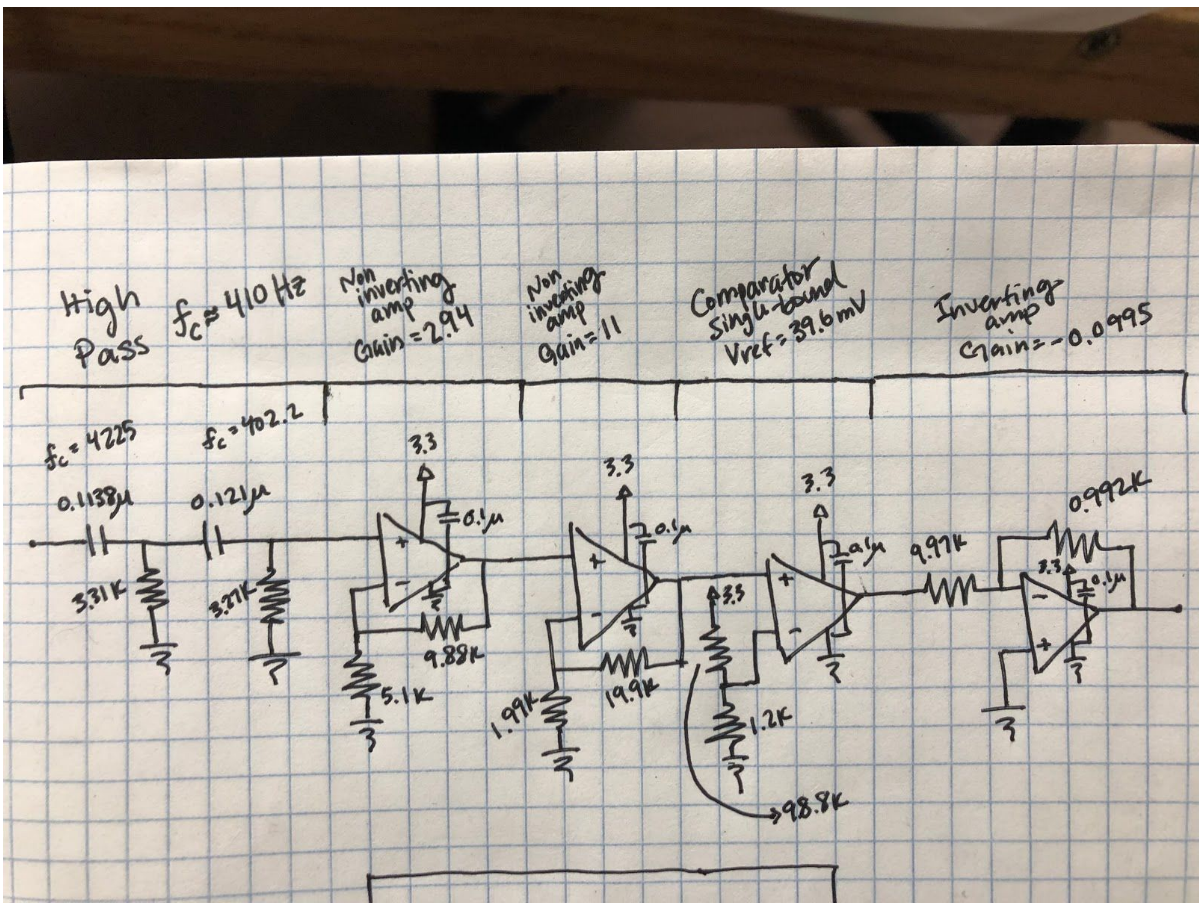
In the final part of this lab we prototyped a slightly modified circuit from last lab onto a more permanent and robust solution, a perfboard. The circuit we used for this lab was nearly identical to the one used in lab 1. The only change needed was to add the 3.3V regulator to support higher drive voltages as well as the diode to protect against reverse polarity. The block diagram and schematics used in the circuit are shown below:



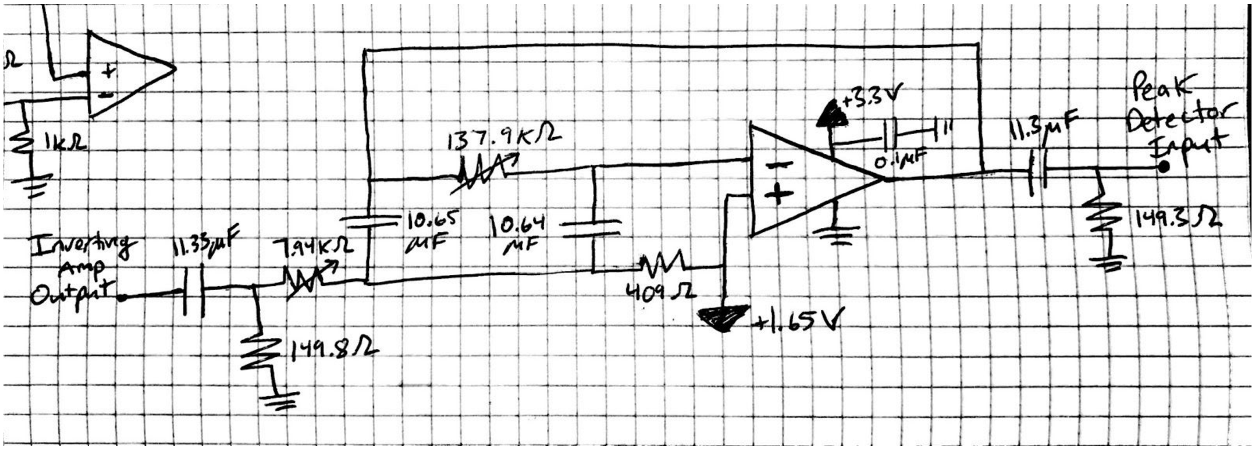
Beacon Detector Block Diagram



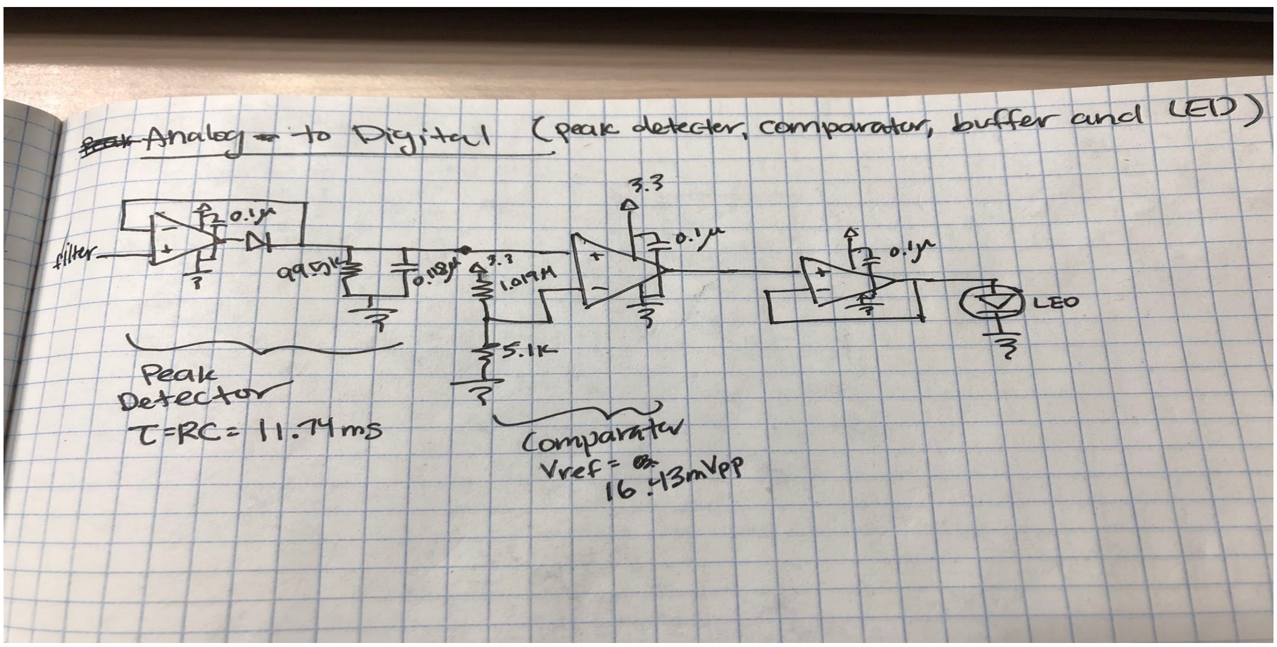
Input Voltage Regulation Schematic



Pre-filtering Stages Schematic



Single Frequency Bandpass Filter Schematic



Analog to Digital Conversion Circuit Schematic

The circuit we used can be broken up into 3 main parts: prefiltering, bandpass filtering, and analog to digital conversion. The first part, prefiltering, starts with the photo-transistor detecting the beacon signal and converting this phenomenon into current flow. The photo-transistor circuit was able to sense the IR square wave emitted by the beacon across the full range of the lab specifications, 1 to 6 feet. The detected square wave was quite small at 6 feet, on the order of 8 mVpp so gain was needed in order to get a usable input signal. We accomplished this by adjusting the resistor on the sinking configuration of the photo-transistor until we achieved a usable signal within the range of detection desired. This signal was fed into the prefiltering stages.

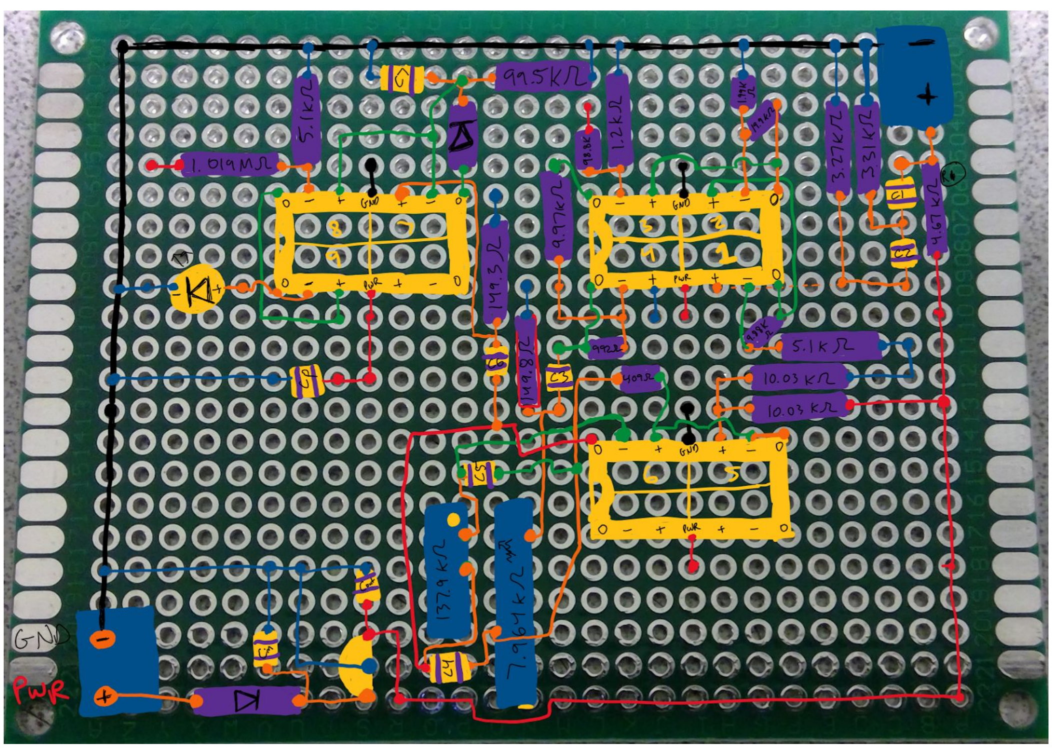
The prefiltering stages consisted of 4 parts: passive high pass filtering, two stages of gain, a single bound comparator, and an inverting amplifier. The initial signal out of the photo-transistor sense circuit has a very high signal to noise ratio, as the 60 Hz noise from the lights was very apparent even with the physical filter. In order to remove this noise before gaining the IR signal, and in turn gaining the noise, we added two high pass passive filters with a cutoff frequency of fc ≅ 410Hz. After this noise was reduced, we gained our signal using 2 stages of non-inverting amplifier gain. Together these gain stages provided Av ≅ 30 and gave us a usable signal for our single bound comparator throughout the full range of detection desired. The single bound comparator was used next, with a tripping bound set at approximately 40mV. We used the comparator in order to remove the distance factor from the circuit, allowing us to need less overall filtering to be able to discern the 2kHz signal from the 1.5 and 2.5 kHz signals. This worked by providing a railed (3.3V) square wave at the frequency which the beacon was giving off. This means that we have exactly the same signal regardless of the distance we are from the beacon. The last thing needed in the pre-filtering stage was to reduce our square wave from 3.3V down to about 330mV using an inverting amplifier with a gain of Av = 0.1. Since our bandpass filter has inherently high gain being G = Q = 10, we needed to reduce the incoming signal as to not rail each frequency on the output of the filter and thus be unable to distinguish the 2kHz from the other frequencies. The prefiltered output signal was then fed into the bandpass filter.

The filter we choose to use was a second order single frequency bandpass filter. We choose this filter as it required relatively few parts and only required a single op-amp. In addition, only a single stage of this filter was required because of the trick we used with the comparator. The single stage filter has a modest attenuation of -55 dB/decade which was more than enough needed to distinguish the 2kHz signal. We inputted a 200 mVPP AC signal from the signal generator directly to the filter to test the circuit before connecting it to the previous pre-filtering stages.The voltages at 1.5 kHz are 0.21 of the peak voltage for one stage and 0.051 of the peak voltage for two stages. The voltages at 2.5 kHz are 0.293 of the peak voltage for one stage and 0.0788 of the peak voltage for two stages. Using two stages of filtering are clearly better at attenuating undesired frequencies, but we did not need that significant of a dB drop to capture the difference between 2 kHz and 1.5/2.5 kHz with the peak detector and comparator. This significantly reduced the amount of circuit components required and saved us time when we have to perfboard the final circuit. The bandpass filtering signal was fed into the analog to digital conversion stages.

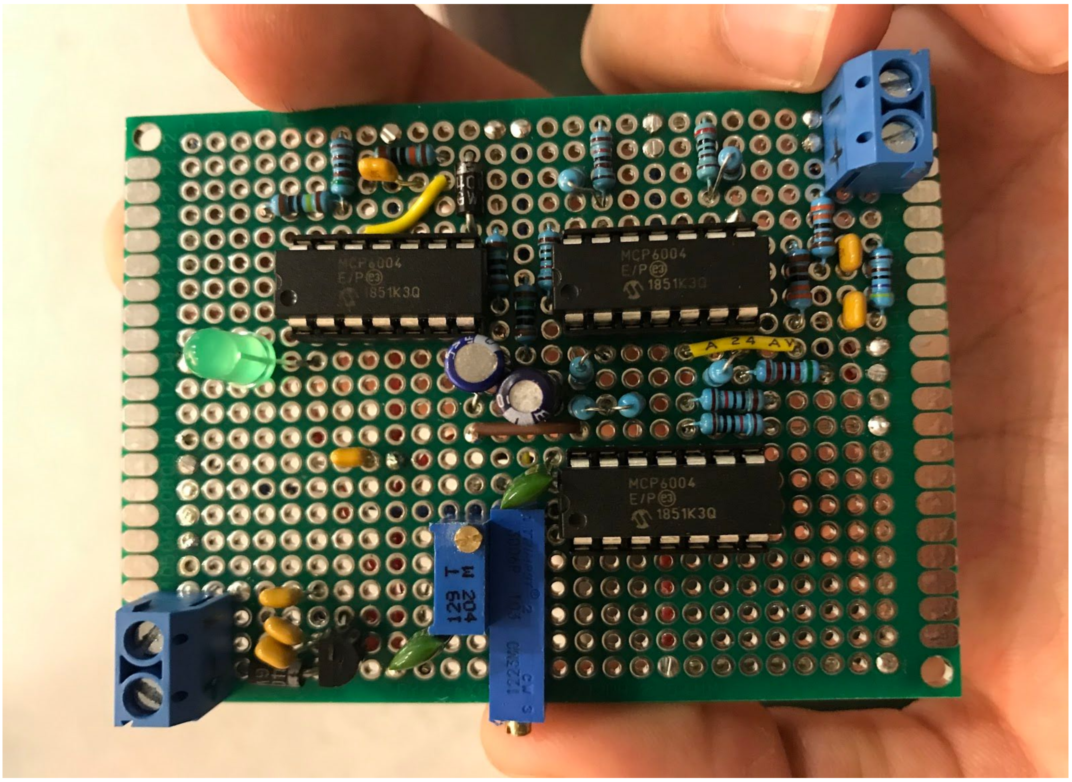
The analog-to-digital conversion stages consisted of the same final stages of the track wire sensor: peak detector, comparator, and LED and buffer. The peak detector captures the maximum voltages of the filtered signals, creating semi-digital signals. We chose a 99.5kΩ resistor and 0.118μ for a time constant of 11.74 ms to work with the 2kHz signal. Since we do not have to detect a range of frequencies, we used a comparator with only a single bound at 16.43 mVPP. Since we used a simple comparator without hysteresis, the high input voltages resulted in the high rail output voltage and vice versa. Due to this switch, we changed the LED driver to connect negative terminal to ground.

Perfboarding the Beacon Detector:

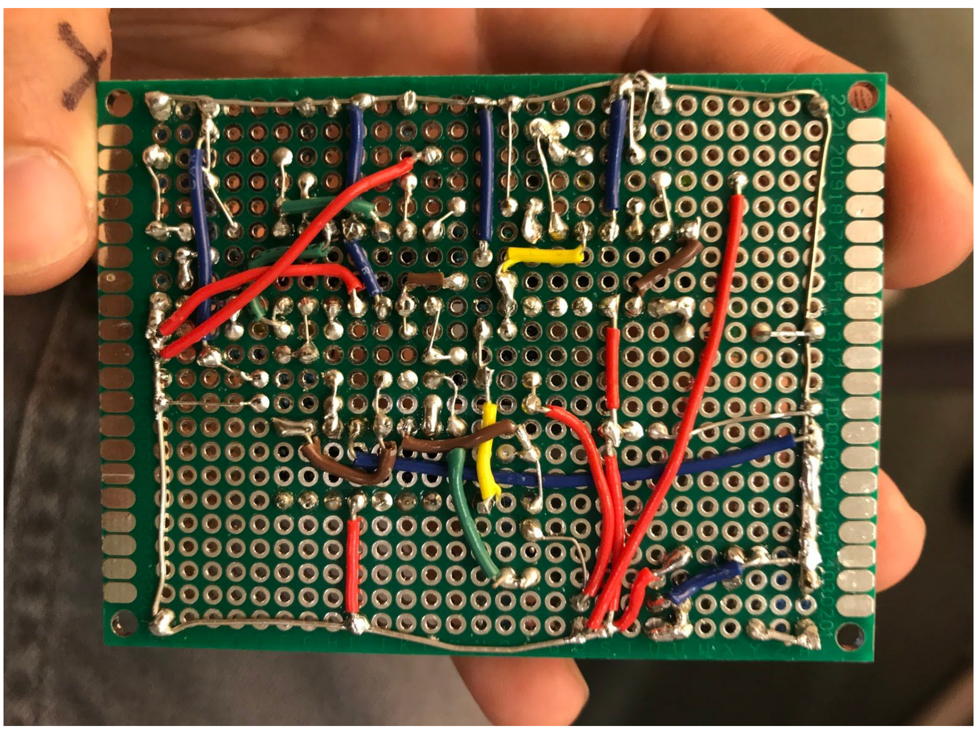
With the circuit for the beacon detector fully laid out including input voltage regulation the final task was to recreate the circuit on a perfboard. We started this by fully laying out the circuit on a picture of the perfboard. We made sure to make sure every pin lined up with the size constraints of the part as well as the space left over. This helped us be sure we would have room for the rest of the circuit as we started soldier. The design also features a main power and ground rail which all necessary components in the circuit utilize. This eliminated the need for an excessive amount of power and ground jumper which converged at a single point on the board. The layout was completed using OneNote on a Surface Pro and was followed to a T resulting in minimal headaches:



Perfboard Layout Schematic



Perfboard Final Working Layout



Bottom View of Final Perfboard Layout

When completing the soldering for the perfboard we made sure to test every single block of the circuit that we added. This essentially meant that every op-amp that was added with its corresponding components was tested before moving on. This process was somewhat time consuming and difficult as it slowed down the overall pace of soldier. In order to verify each part was working we used the original breadboarded circuit alongside the perfboarded circuit. Before moving on the signal responses was verified to behave exactly the same as the original circuit. Through this process we found 2 issues, both being an incorrect swapping of connections between the positive and negative terminals of the op-amp. Although this process took extra time up front it resulted in much less headache overall. The only de-soldiering that occurred was to fix the two minor issues, and otherwise everything worked perfectly first try. The pin by pin layout certainly help the initial soldier as well. Overall due to ample preparation and diligence the perfboard soldier took about 12 hours with very minimal headache.

Conclusion

This lab provided valuable insight into bring designs that more on paper into the real world. The platform, tower and gearbox designs allowed us to work with CAD and get trained on using the laser cutter. Use of the laser cutter and similar machines will be important in rapidly prototyping out designs for the final lab as well as projects throughout our life. In addition to the mechanical design experience, this lab gave us a chance to work on our soldering skills. Perfboarding will be a useful technique in prototyping robust circuits that need to work in the real world, as a breadboard doesn't cut it for most applications out of lab. Overall, we feel much more prepared and capable of physically building our electrical and mechanical designs in the future.

Justin Fortner

Summary and Time Tracking

Time Spent out of Lab	Time Spent in Lab	Lab Part - Description
0	1 hr	Part 0 – SolidWorks Basics
0	2 hrs	Part 1 – A Simple Gearbox
0	8 hrs	Part 2 – Designing a Motorized Platform
		Part 3 – Prototyping the Motorized Platform
0	16 hrs	Part 4 – Beacon Detector on Perfboard

Checkoff: TA/Tutor Initials	Lab Part - Description
VN	Part 1 – A Simple Gearbox
VN	Part 2 – Designing a Motorized Platform
ZP	Part 3 – Prototyping the Motorized Platform
ZP	Part 4 – Beacon Detector on Perfboard
CD	Pre Lab

Max Smalley

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VN	Part 1 – A Simple Gearbox
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ZP	Part 3 – Prototyping the Motorized Platform
[illegible]	Part 4 – Beacon Detector on Perfboard
CP	prelab