Daniel Mendez: Board 2 Report

Project Overview

This project involved comparing the effects that bad layout practices have on certain figures of merit within a circuit. The two circuits compared were identical in function in that they were simply hex inverters fed a 50% duty cycle and 500hz square wave generated by an astable vibrator (555-timer) The Plan of Record:

- A 555-timer configured as an astable vibrator.
- The frequency of the 555 outputs to be 500 Hz with an error margin of +/- 100 Hz
- The duty cycle of the 555 outputs to be 50% with an error margin of +/- 18
- A Two Hex Inverters with contrasting configurations:
    - A far decoupling capacitor(Bad) vs A near decoupling capacitor(Good)
    - A common ground trace connection(Bad) vs a continuous ground plane (Good).
- Both Hex inverters would have a Quiet high and low output to measure rail noise
- Both Hex inverters would drive 3 red LED's.
- Indicator LEDs for the power of the circuit
- A 5V supply for the entire circuit
- 1206 components to be used.
- The circuit can be powered by the 5V supply directly or the 3.3v LDO regulator output.
- A Filter capacitor is added at the power input but with a switch so noise with and without it can be measured.
- The board would be brought up with no jumper switches connected, then the 5v jumper is connected as a power source, then the 555 is powered, then each hex inverter would be powered first separately then both of them.
- Measurements of rise/fall times as well as noise levels would be done both with 5v and 3.3v and also with and without the input power filter capacitor.

A basic sketch of the initially planned schematic is shown below:

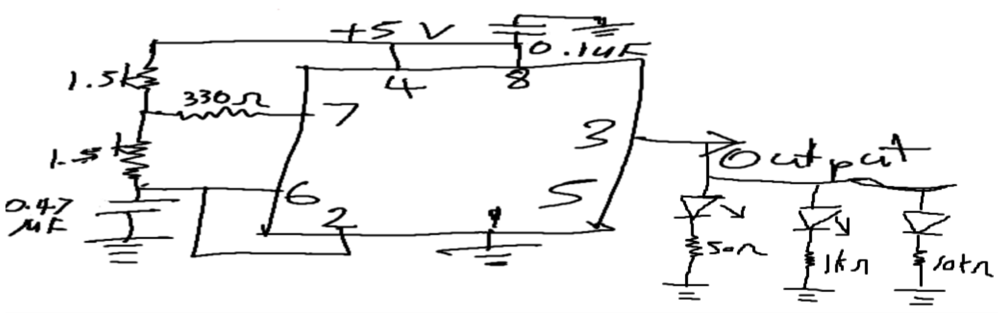

Figure 1 Basic sketch of the intended circuit.

The Altium schematic that was created based on this is shown below:

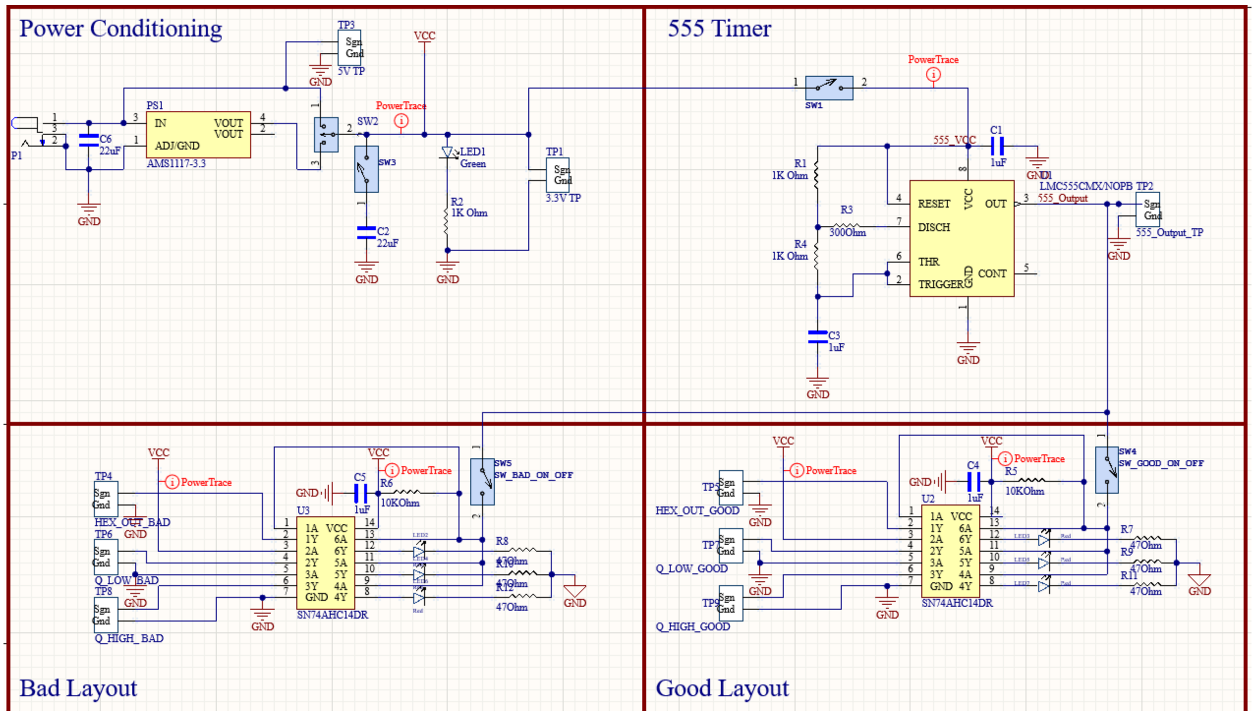

Figure 2 Board 1 Schematic

The board layout that was developed based on this is also shown below:

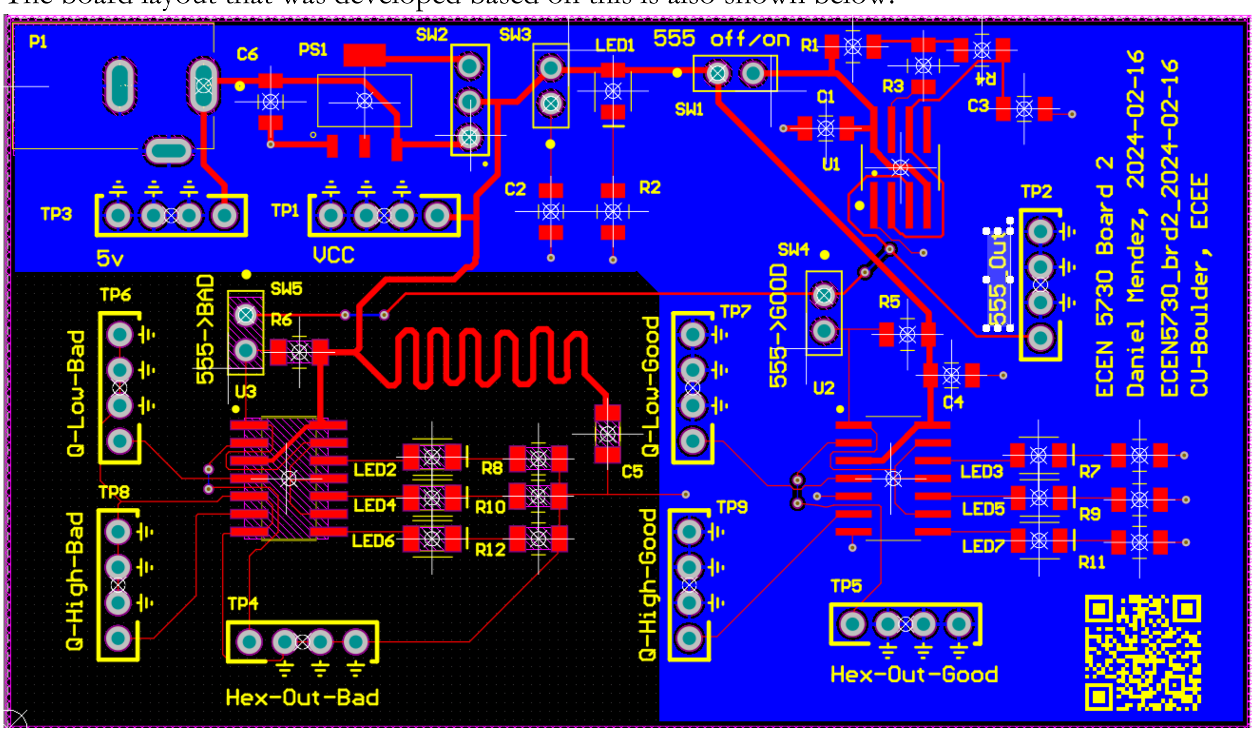

Figure 3 PCB Layout of Board 1

The printed circuit board is shown below as well as the assembled version.

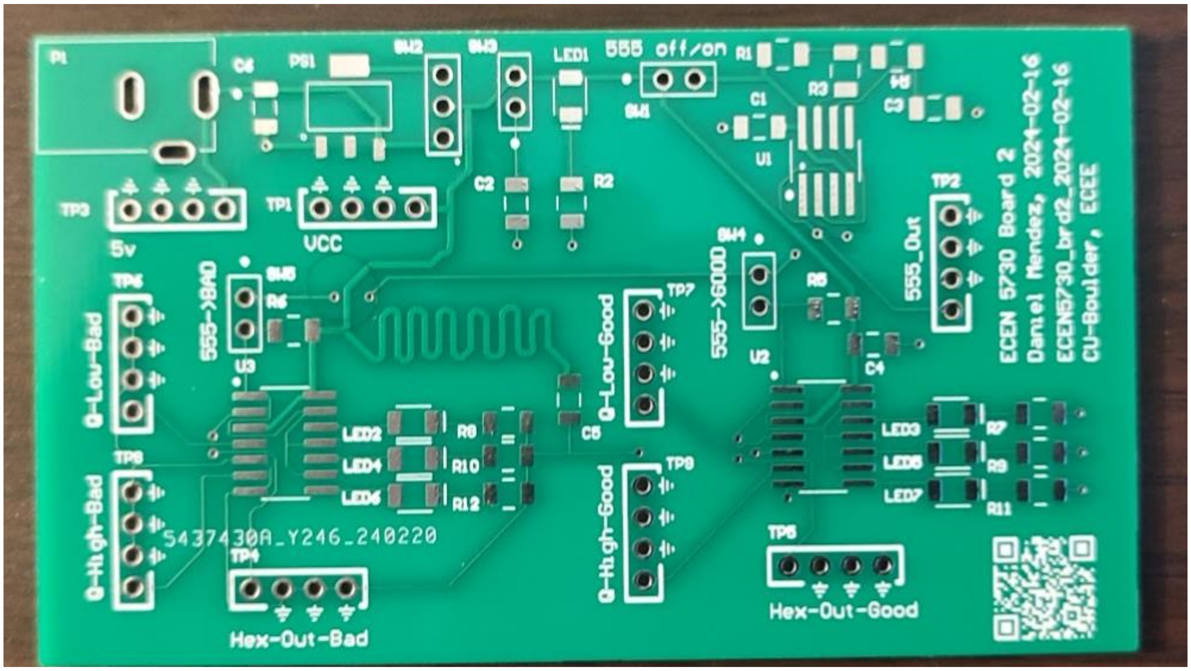

Figure 4 Printed PCB

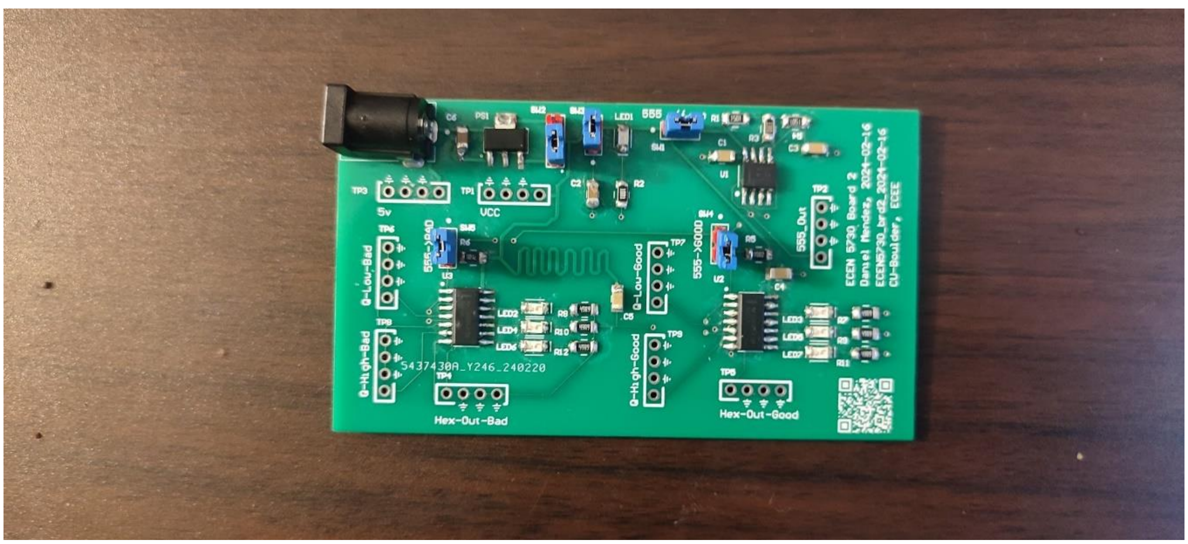

Figure 5 Assembled PCB

What worked

Based on the plan of record, my definition of the circuit working included specifications for the duty cycle, the frequency as well as the indicator LED’s. Both hex inverters worked on 5v as well as 3.3v but of course there was differences which can be seen in measurements. The images below is a comparison of the rail noise present when 3.3V and the filter capacitor is connected vs when it is not.

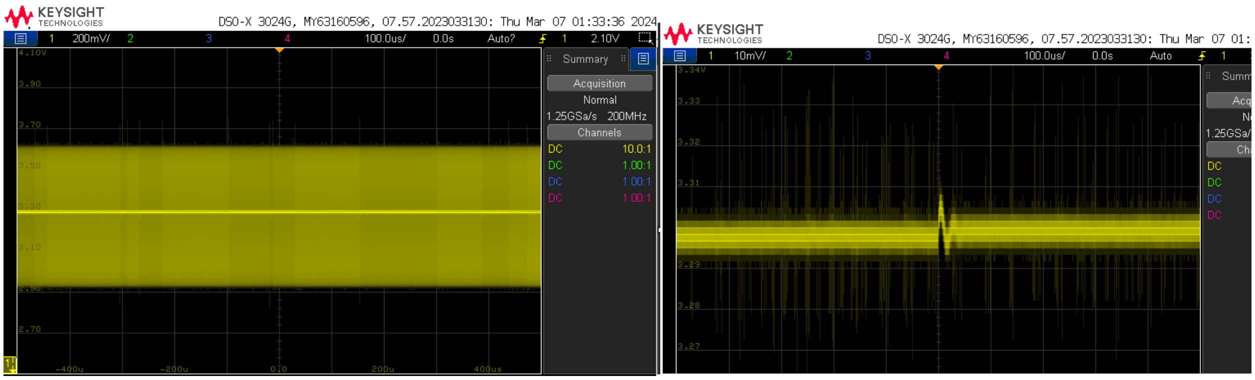

Figure 6 Filter Capacitor Off (Left) vs Filter Capacitor On (Right)

Notice on the left, there is much higher peak noise driving VCC to a sustained 3.6V whereas there is much less noise on the right and VCC stays to around 3.3V as intended. Next we can compare the rise and fall times of the 555-timer using a 5v vs a 3.3v supply.

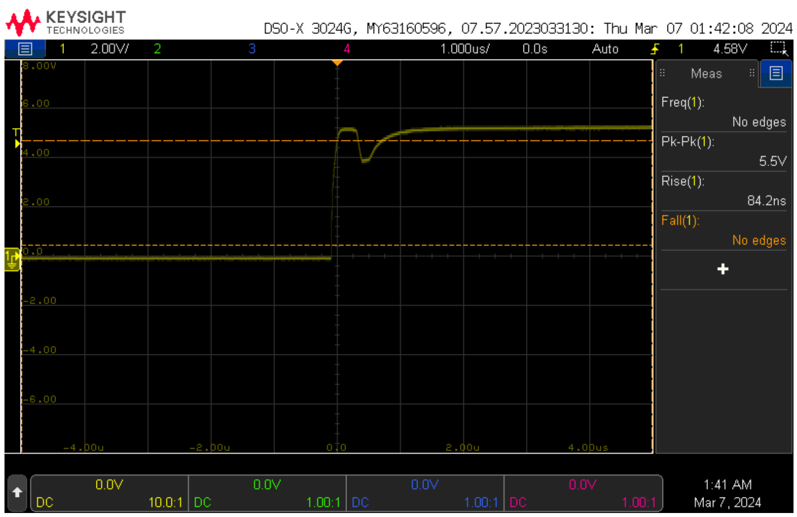

Figure 7 555 output rise time 5v supply

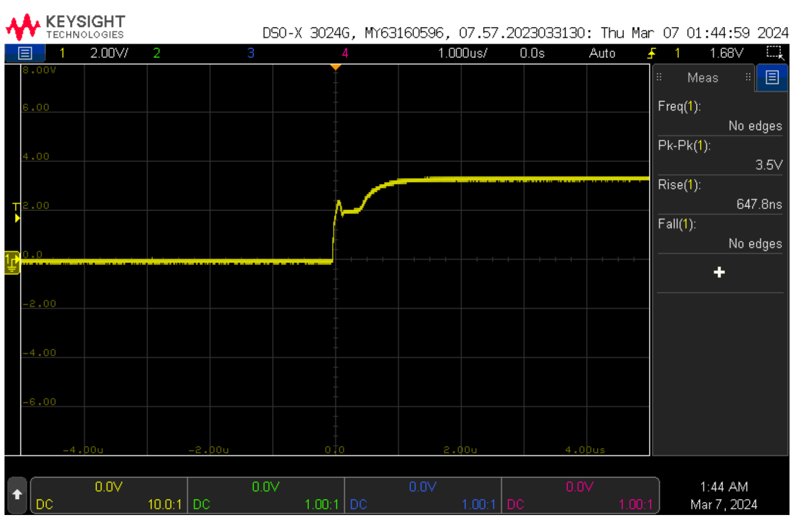

Figure 8 555-output rise time 3.3v supply

From the two images above, it is clear that with a higher VCC, there is a much shorter rise time since a higher voltage means more current meaning a shorter charge time. A similar trend is seen in the fall times as with 3.3v the fall time is 79.6 nanoseconds whereas with 5v the fall time was 15.8 nanoseconds.

To find the Thevenin output resistance of the hex inverter, Using the good layout, I measured the voltage drop across the 47-ohm resistor which is shown below:

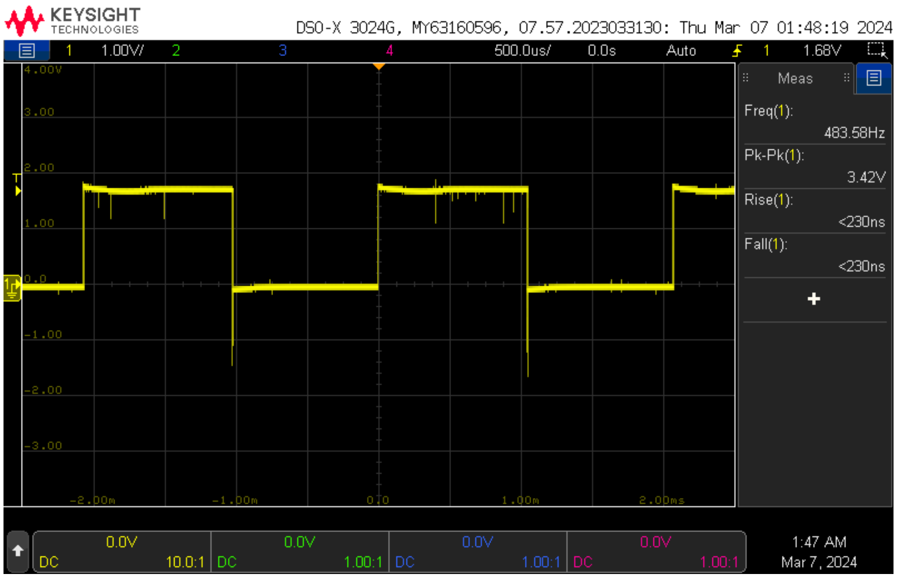

Figure 9 47-Ohm resistor waveform

At peak output, the voltage across this is around 1.77Volts. Then I measured the voltage drop across the output LED in series. This was around 2.25 Volts which is in keeping with the datasheet range of 1.75 to 2.35V. This means the Thevenin resistance of the Inverter is given by.

$$R_{Th} = \frac{V_{Th}}{I} = \frac{5 - (2.25 + 1.8)}{(\frac{1.8}{47})} = 24 \; ohms$$

Next, as we predicted, there are differences in the figures of merit due to the good vs bad practices. In the bad practice circuit. That had a further bypass capacitor and a common ground plane, there was much more ground bounce present at the Quiet low output as well as more noise present at the Quiet High output. That means the internal rail within the IC is being disrupted on both ends.

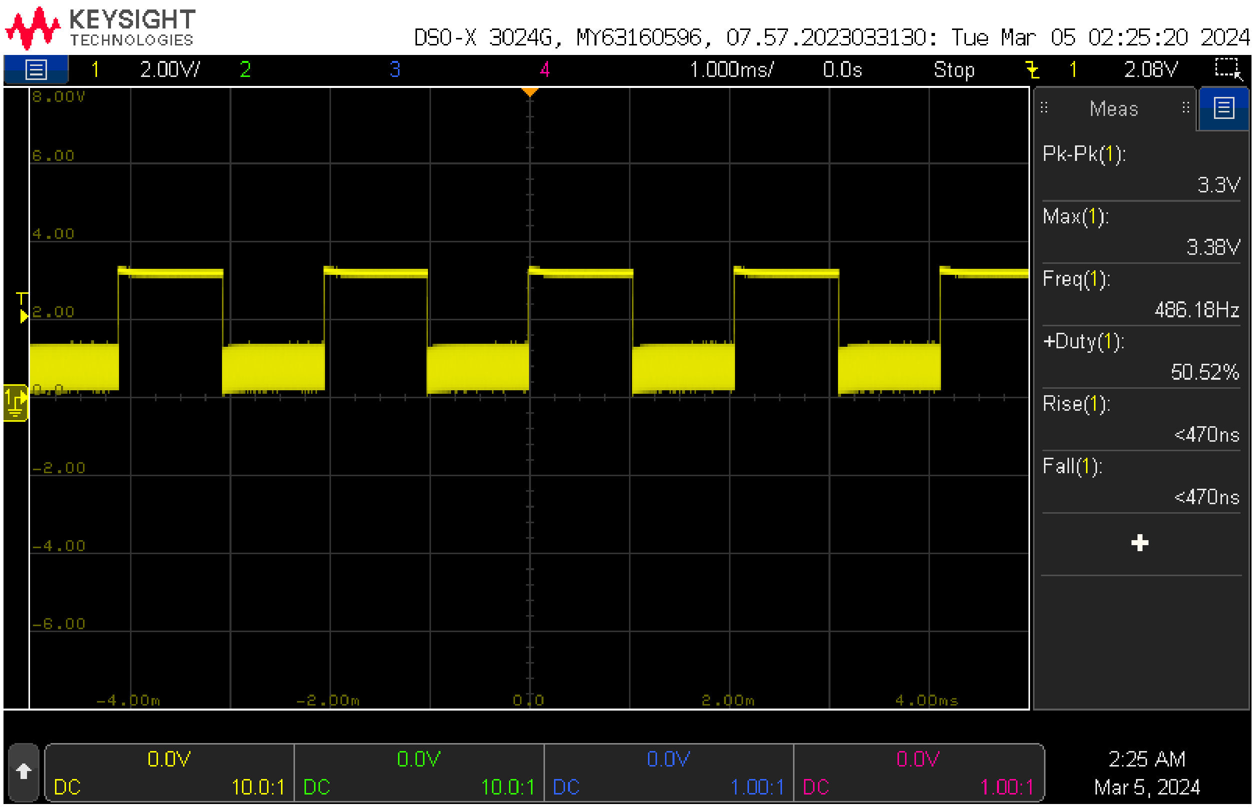

Figure 10 Bad hex layout output.

The bad hex output is shown above and notice there is significant noise when the signal should be low. The good hex output was similar to a regular square wave without the noise artifacts seen here.

With regards to Quiet High and Quiet Low. There was significantly more noise on the Quiet High and Quiet low of the bad hex layout which follows what is seen in the previous picture. This quiet high noise can be attributed to the far location of the decoupling capacitor which leads to inappropriate quenching of the noise spikes. When on the 3.3V supply, the voltage was as high as 3.57 Volts at some instants. Noise on the Quiet Low lines would be attributed to the shared ground traces.

Analysis of Project

Things which worked well, and I would like to do in my future designs:

- Placing decoupling capacitors as close as possible to the IC as possible
- Giving myself as much time as possible, This would learning I should use a larger PCB and I could have placed the decoupling capacitor even further away.
- Using my own resistor values as I wanted to use the 3-resistor circuit to get the duty cycle and frequency as close as possible to 50% and 500Hz respectively.

- Using jumper switched to isolate parts of the board during bring up. This was great so I can verify each subsection's functionality before connecting the rest of the board.
- Labelling the resistors at the 555 outputs made it very easy to tell which was which.

Everything worked as intended for this design fortunately and there were no hard errors.

Soft error wise, I believe there is some things I could improve.

- I should triple check the layout before exporting the files as I had typos in my silk screen labelling, and I had to redo it and regenerate the files.
- When soldering I believe I am using too much solder still, I need to let the flux do more of the work.
- I need to manage time better so I can have more time with the layout for this board.