

Project Overview:

POR:

1. Rough Schematic / Block Diagram

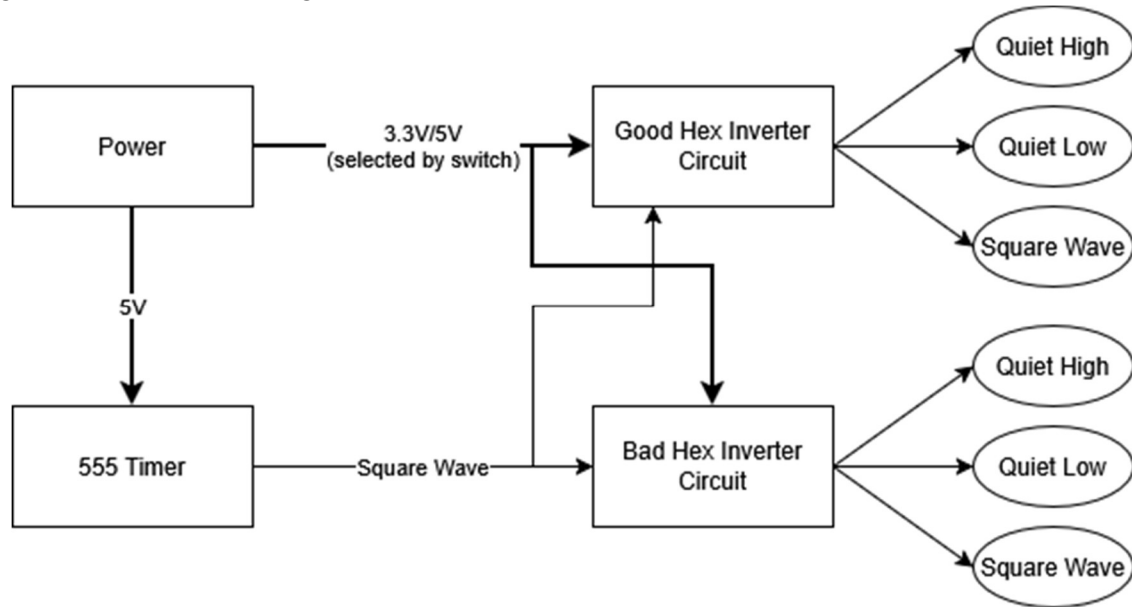


Figure 1: Block diagram of the board.

1. Significant Parts

- a. 5V to 3.3V LDO (AMS1117-3.3, SOT-223 package)
 - i. <http://www.advanced-monolithic.com/pdf/ds1117.pdf>
- b. 2x hex inverter (74AHC14, SOIC package)
 - i. <https://www.ti.com/lit/ds/symlink/sn74ahc14-ep.pdf?ts=1758637674826>
- c. 1x 555 timer (TLC555, SOIC package)
 - i. https://www.ti.com/lit/ds/symlink/tlc555.pdf?ts=1758608908071&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FTLC555

2. Definition of “Working”

- a. 400-800Hz output of 555 with 40%-75% duty cycle
- b. One hex inverter is in a very noisy environment, the other in a less noisy environment
- c. Thevenin resistance of hex inverter is measurable
- d. LEDs output light
- e. Each hex inverter has a quiet high and quiet low
- f. Hex inverters can be powered by 3.3V or 5V
- g. Test points accommodate 10x probes with springs

3. Schedule

- a. 2025-09-23 – POR
- b. 2025-09-24 – CDR
- c. 2025-10-10 – Assembly and test

d. 2025-10-15 – Report

4. Test plan

a. LDO

- i. Connect power, probe TP1 to verify power is supplied
- ii. Connect LDO
- iii. Probe TP2 without then with decoupling cap enabled
 1. Verify ~3.3V is supplied
 2. Expect ~1MHz oscillations w/o decoupling capacitor
 3. Collect scope shots w/o then with decoupling capacitor enabled.

b. 555 timer

- i. Power on 555
- ii. Probe TP5 to verify 555 output frequency is ~500Hz at ~50% duty cycle

c. Hex inverters

- i. Connect both hex inverters to 5V
 1. Probe quiet high, quiet low, and V_{R_LED} simultaneously for each hex inverter. Trigger using trigger output of hex inverter.
 - a. V_{R_LED} should have a high base of approximately 1.3V
 2. Measure noise on quiet high and quiet low on each inverter. Save scope shots with measurements.
- ii. Connect to 3.3V
 1. Repeat all tests in 3.3V step, except expect V_{R_LED} to have a high base of approximately 3V.

5. Power budget and supply

a. Power brick can supply 5V @ 0.2A

- i. Estimated LED current = $3 * 3V / 50\Omega = 3 * 0.060 \text{ A} = 0.18 \text{ A}$
- ii. Estimated LED power draw = $3 * (3V)^2 / 50\Omega = 3 * 0.18 \text{ W} = 0.54 \text{ W}$

b. LDO can supply 3.3V @

- i. Estimated LED current = $3 * 1.3V / 50\Omega = 3 * 0.026 \text{ A} = 0.78 \text{ A}$
- ii. Estimated LED power draw = $3 * (1.3V)^2 / 50\Omega = 3 * 0.034 \text{ W} = 0.10 \text{ W}$

6. Potential risk sites

- a. Using wrong size or capacity components (resistors and LEDs)
- b. Using a wrong model LDO
- c. Soldering parts backwards
- d. Powering with a supply >5.5V (controlled by hex inverters)
- e. Soldering LEDs backwards

Board Layout:

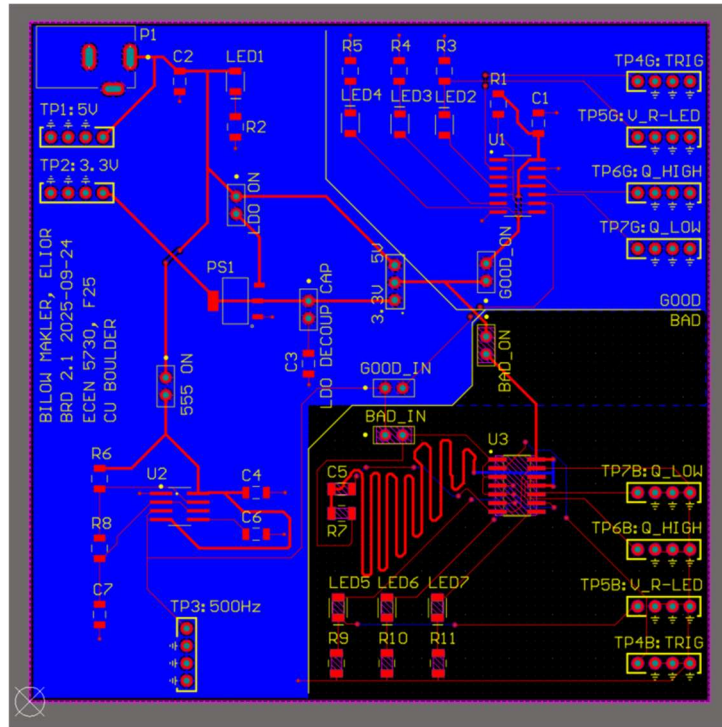


Figure 4: Board layout in Altium. (Red: top layer; Blue: bottom layer; Yellow: top silk screen)

Picture of Bare Board:

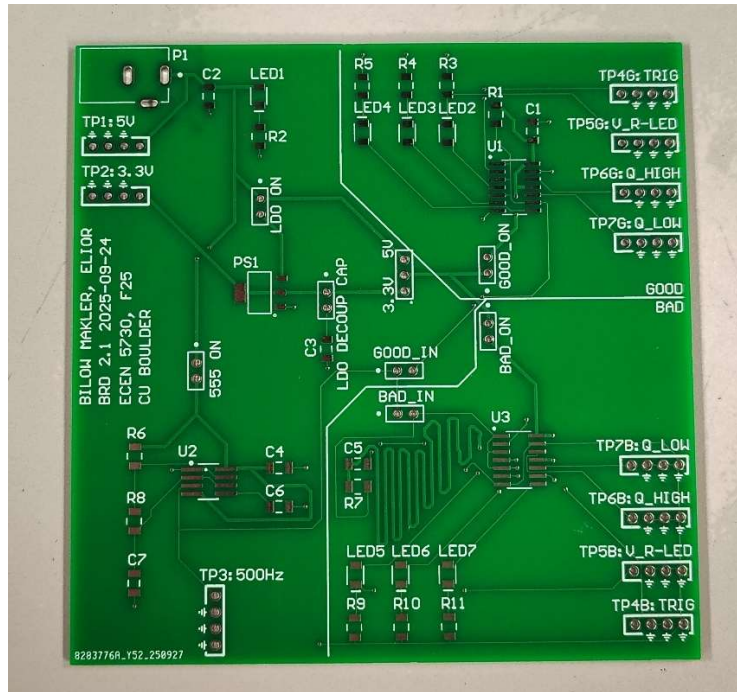


Figure 5: Bare PCB received from the board manufacturer.

Picture of Assembled Board:

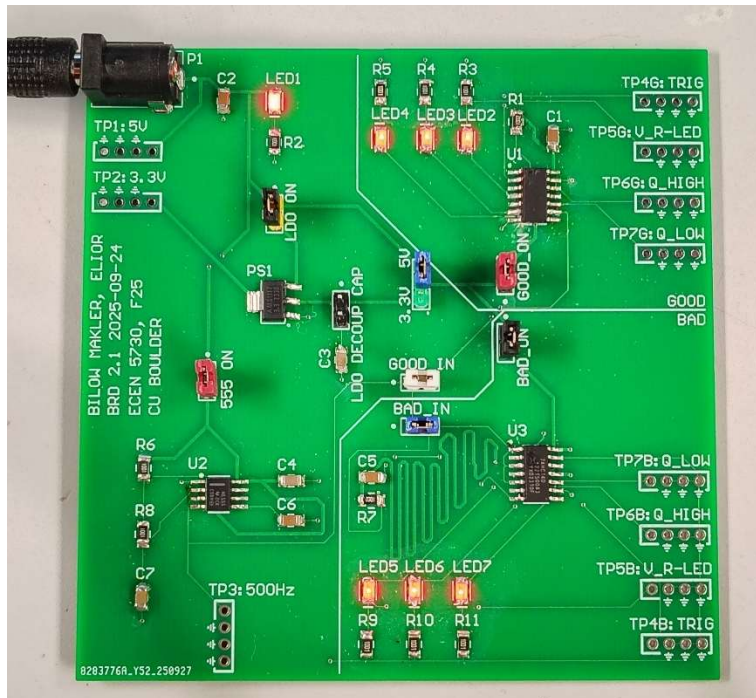


Figure 6: Assembled board powered on

Testing and Validation (What Worked):

555 Timer Output:

The 555 timer was met the required output of 400-800Hz with a 40%-75% duty cycle.

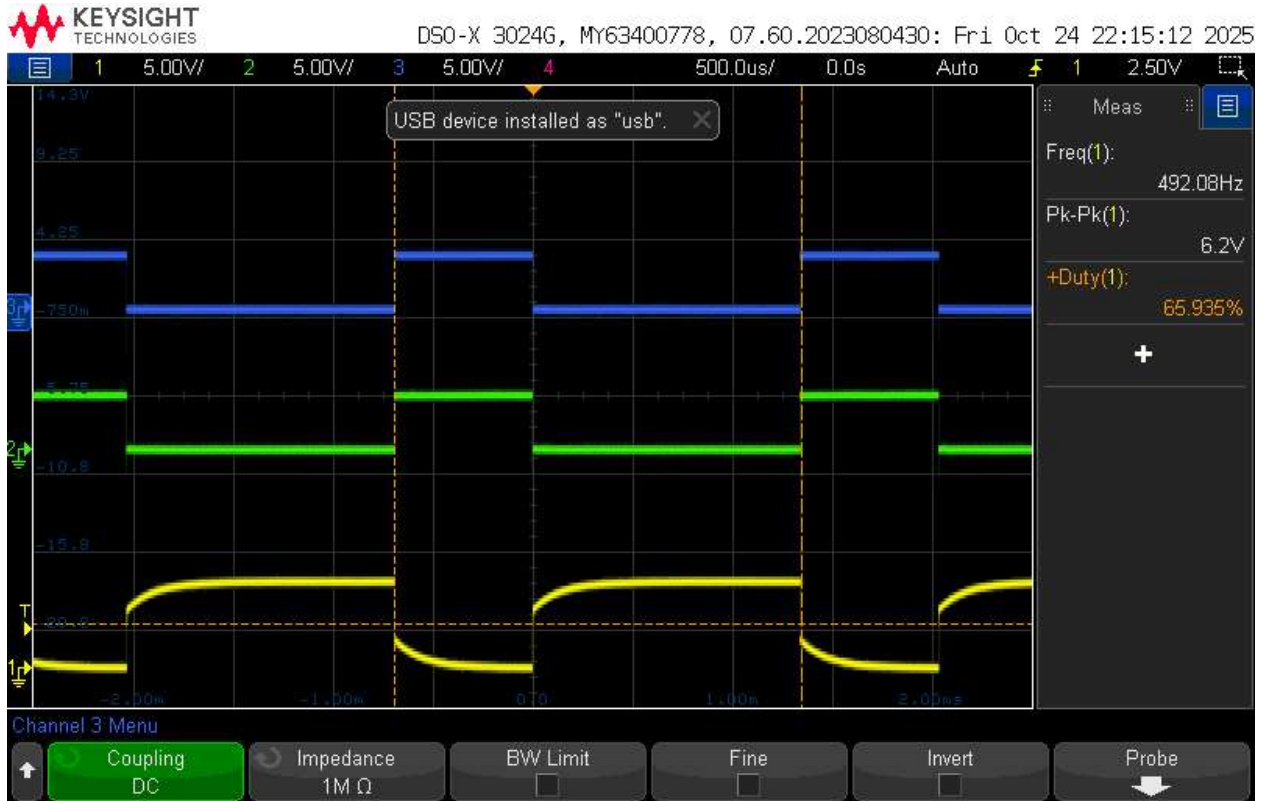


Figure 7: 555 Timer output (in yellow), and the hex inverter LED outputs (in blue and green).

Hex Inverter Performance Comparison:

The good hex inverter had 25.5% noise on the power rail and 51.6% less ground rail noise. This is consistent with what I expected since the good design follows best practices, such as a continuous return plane and decoupling caps placed near the chip.

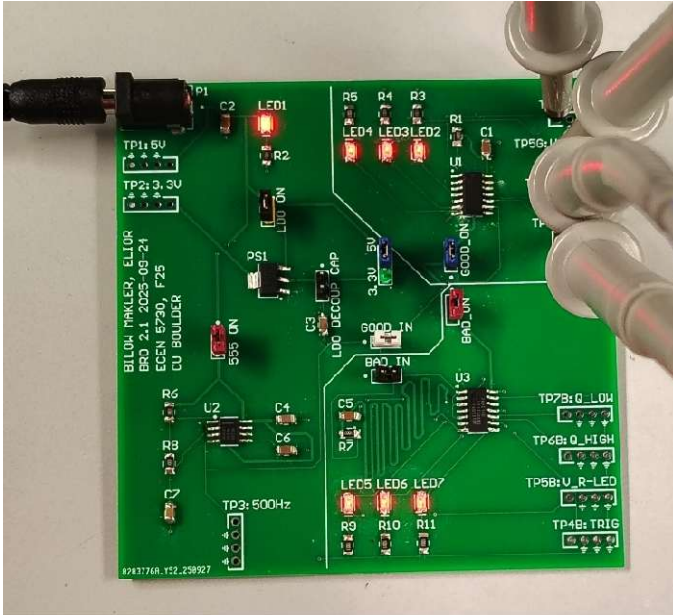


Figure 8: Good hex inverter test configuration.

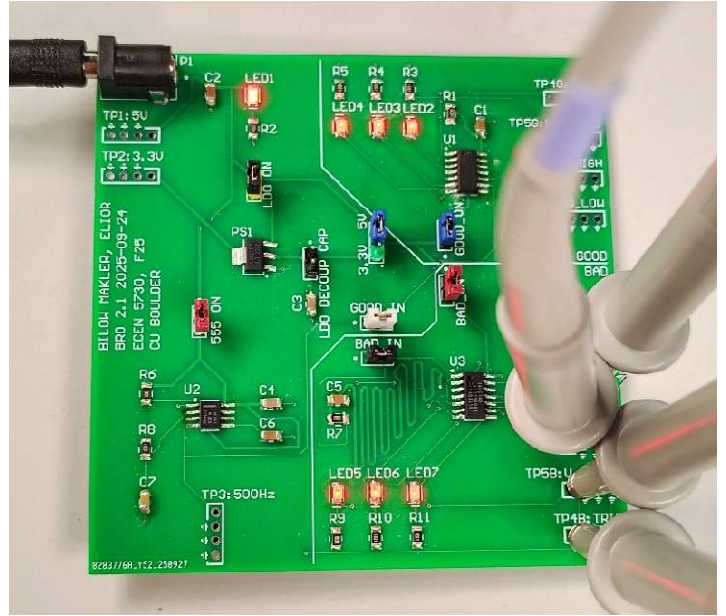


Figure 9: Bad hex inverter test configuration.

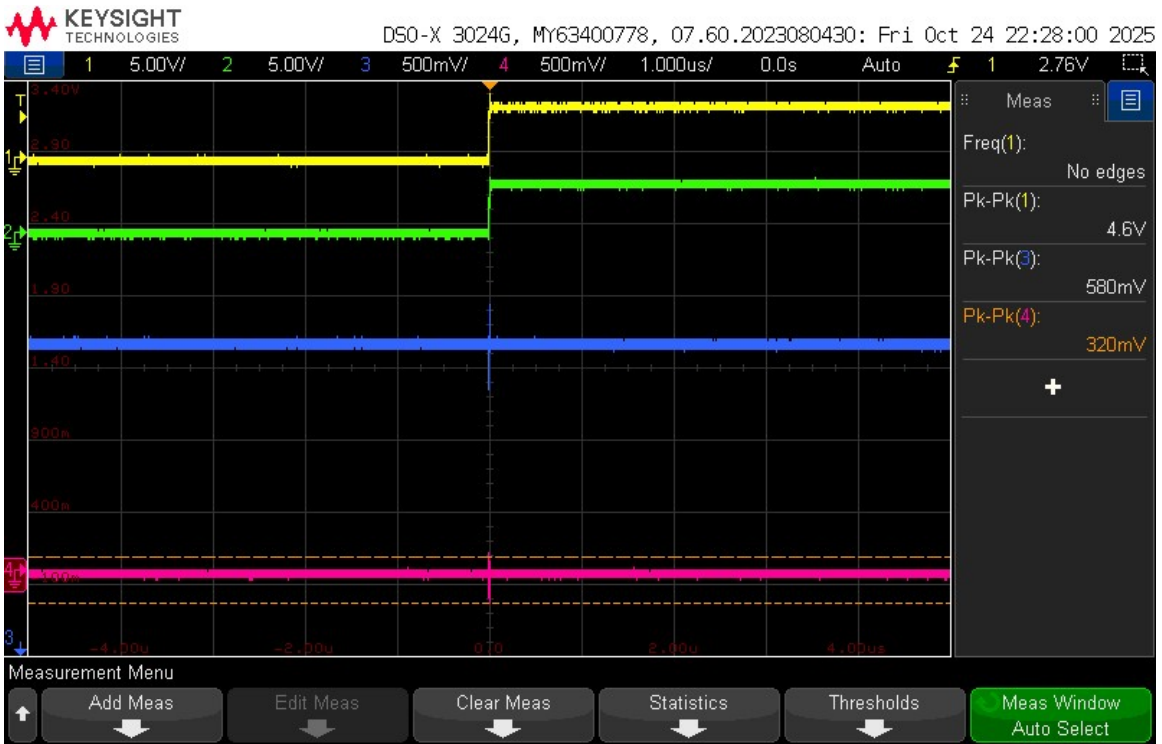


Figure 10: Good hex inverter oscilloscope readings. (Yellow: trigger; Green: voltage across an LED resistor; Blue: quiet high; Pink: quiet low)

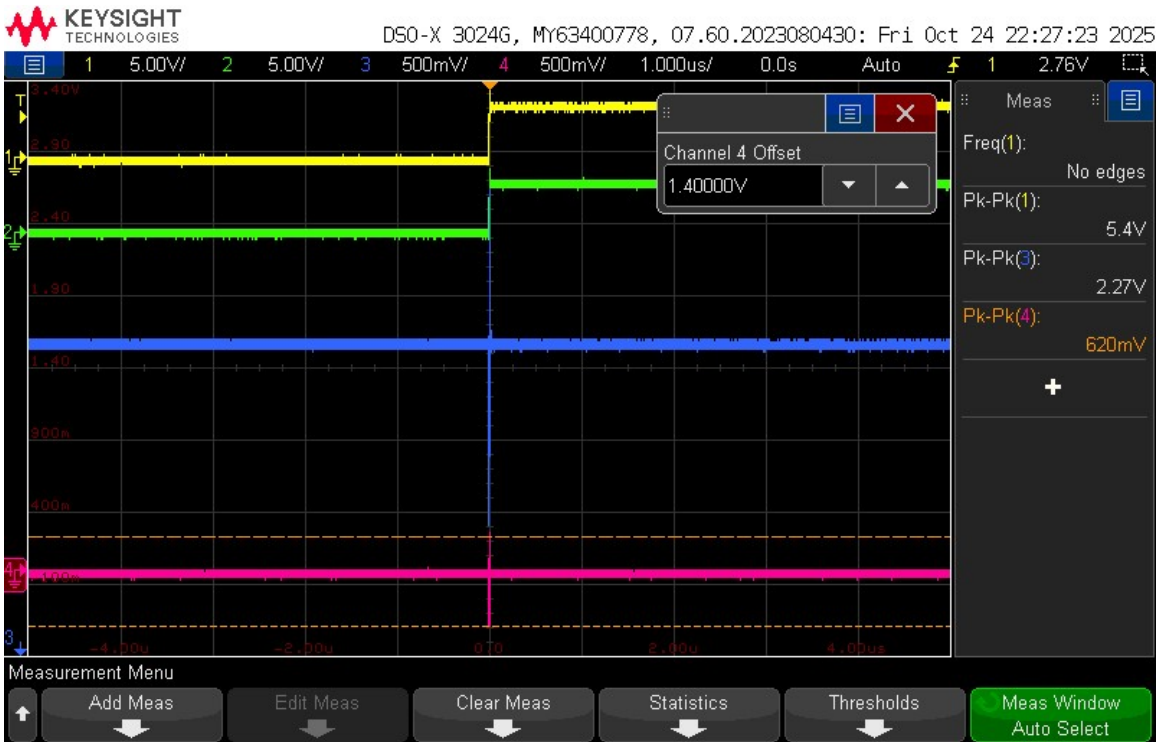


Figure 11: Bad hex inverter oscilloscope readings. (Yellow: trigger; Green: voltage across an LED resistor; Blue: quiet high; Pink: quiet low)

Thevenin output resistance:

The voltage of the quiet high output was 5.55V. This is the Thevenin voltage. The voltage across one of the 1kΩ resistors was 3.46V, meaning that the load current 3.46mA. The voltage drop across both the LED and the resistor was 5.33V, making the voltage drop across the “Thevenin resistor” 0.22V under a 3.46mA load. Therefore, the Thevenin resistance is 64Ω.

$$\frac{5.55\text{ V} - 5.33\text{ V}}{3.46\text{ V} / 1000\Omega} = \frac{0.22\text{ V}}{0.00346\text{ A}} = 64\Omega.$$

Equation 1: Thevenin resistance calculation

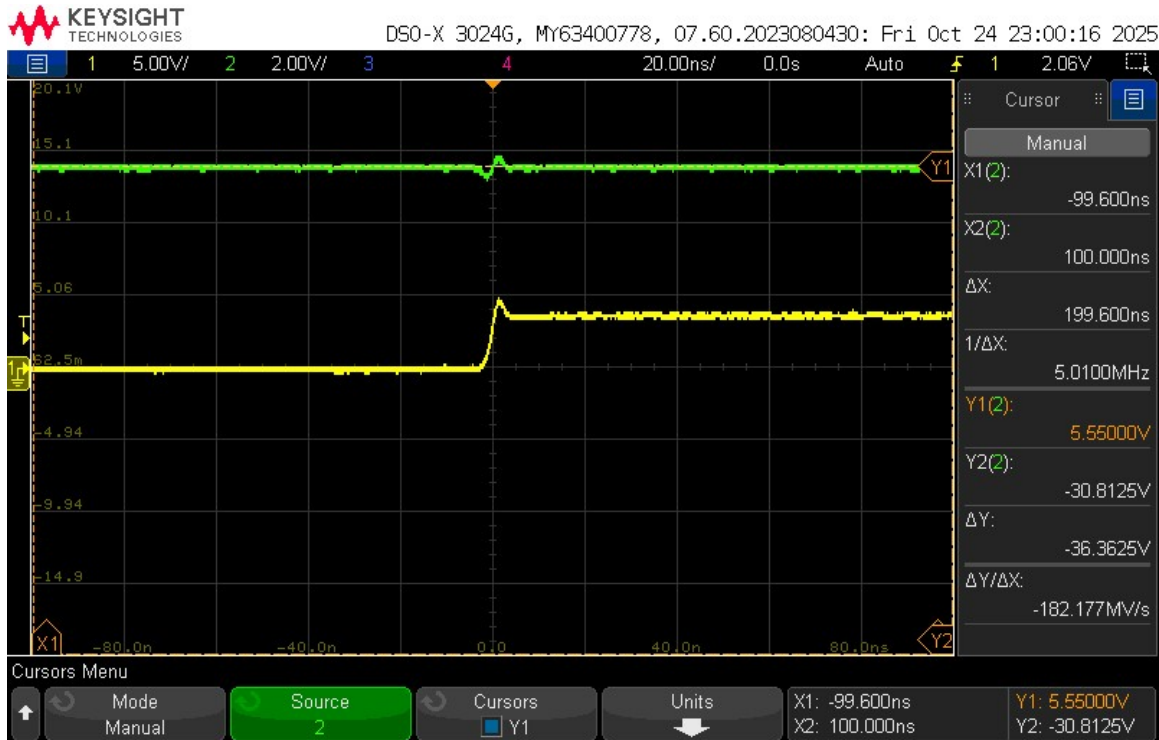


Figure 12: Quiet high voltage reading (green).

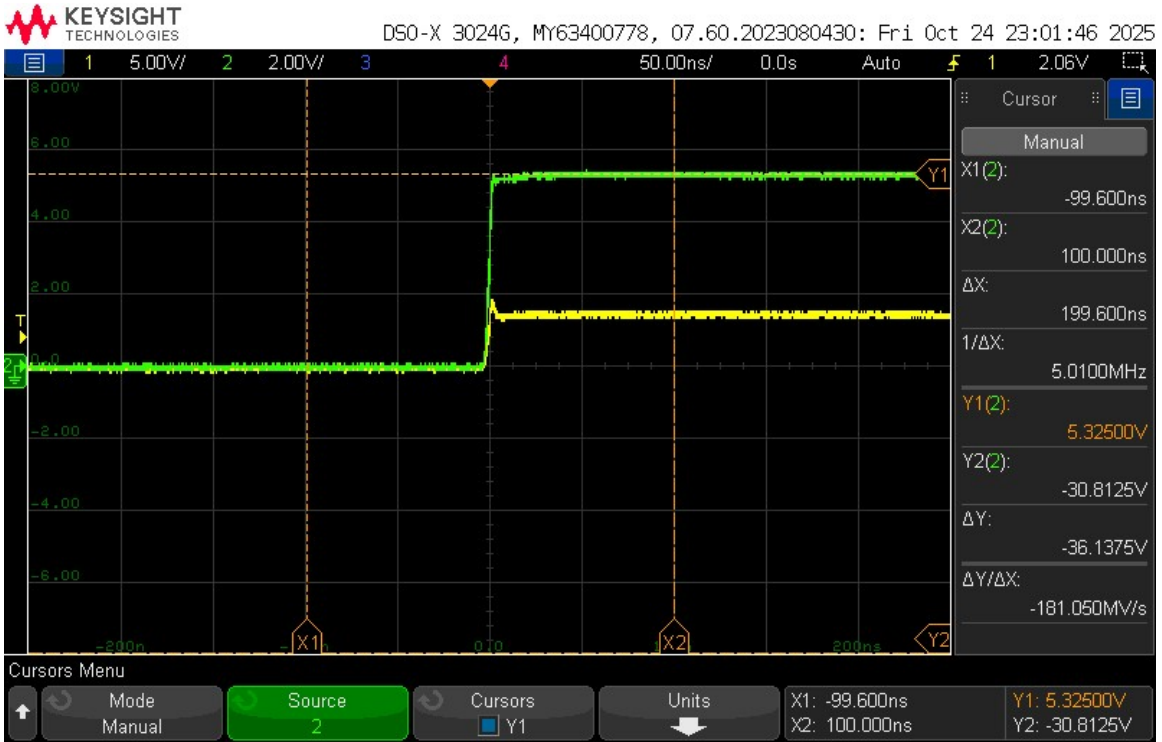


Figure 13 Voltage reading across LED and resistor (green).

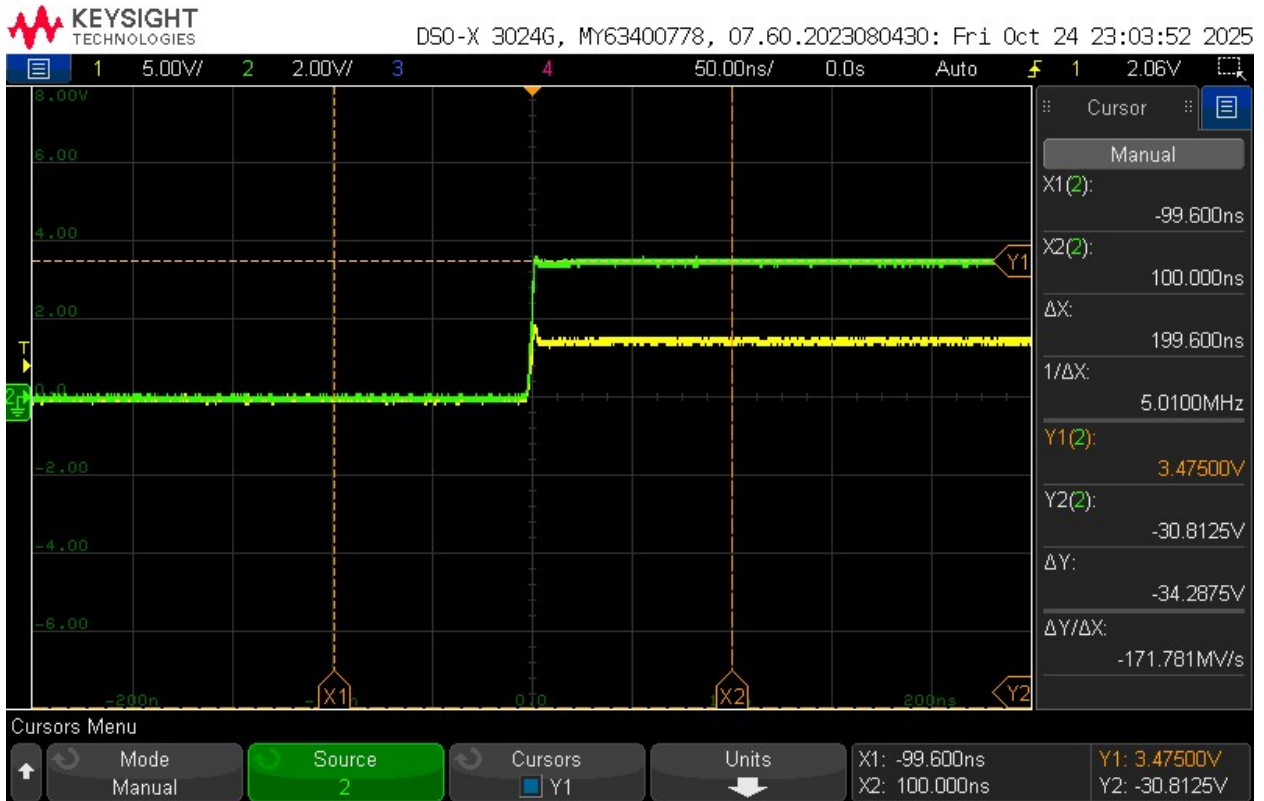


Figure 14: Voltage reading across the 1kΩ LED resistor (green).

LED Visibility:

The LEDs were emitting light as expected when powered on.

Oddly, the hex inverter LEDs (on both the good and the bad circuit) emitted dim light when the hex inverters were not powered but when the 555 output was feeding into the hex inverters. This is likely because the 555 timer provides enough power to the hex inverter to supply some amount of output power. This hypothesis is supported by the fact that the peak-to-peak voltage is much lower on both the 555 timer output and the LED when the hex inverter is not powered but the 555 output is feeding into the hex inverters (25.4% lower on the 555 timer output 68.9% on the LED).

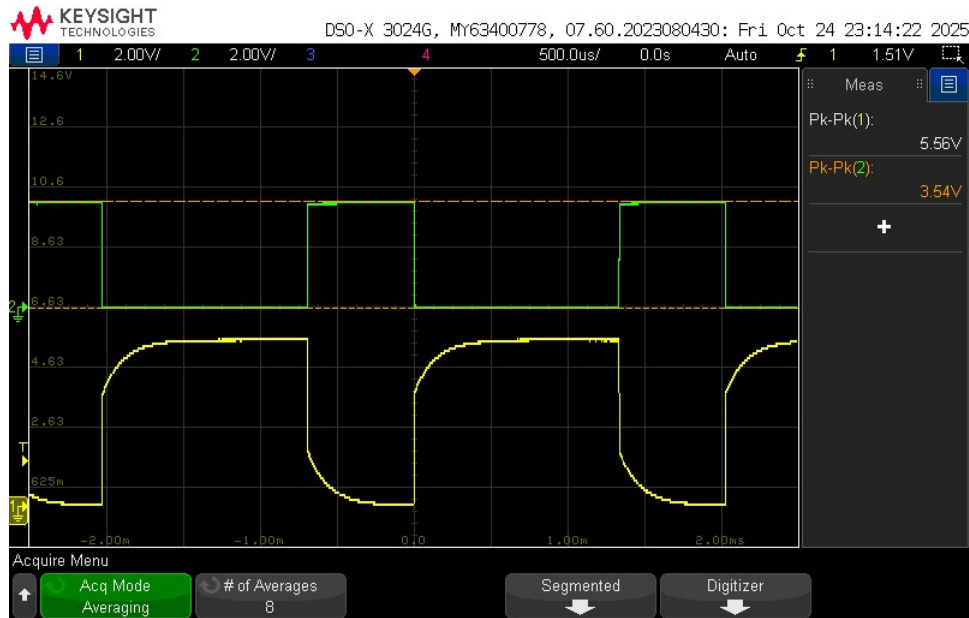


Figure 15: 555 output (yellow) and good hex inverter LED output (green) under normal conditions (hex inverter powered and 555 output feeding into the inverter).

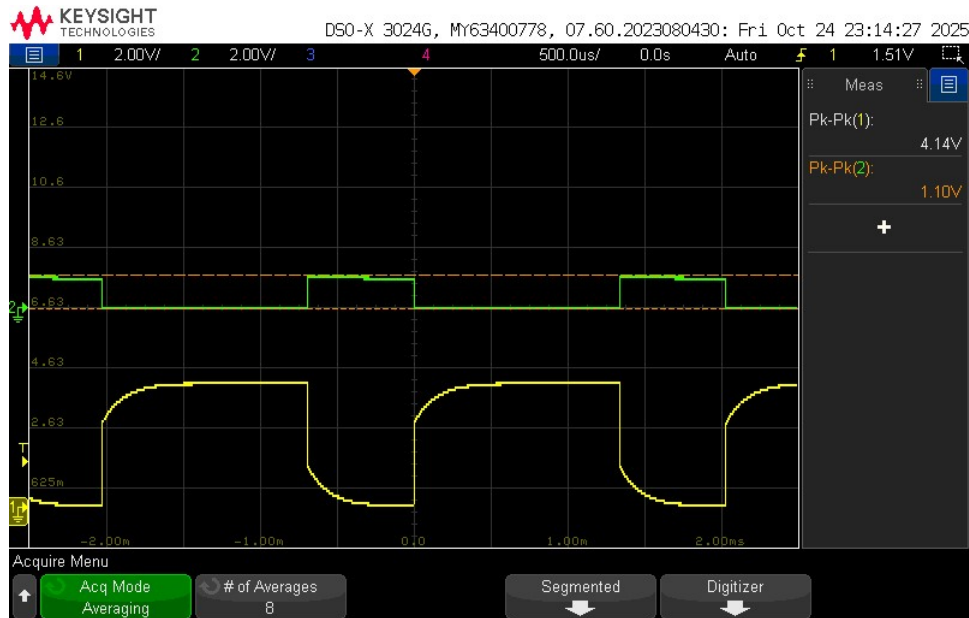


Figure 16: 555 output (yellow) and good hex inverter LED output (green) under abnormal conditions (hex inverter not powered and 555 output feeding into the inverter).

Test points accommodate 10x probes with springs:

The test points accommodated 10x probes, though they were spaced very closely so it was difficult to hook up all four probes next to each other simultaneously.

Each hex inverter has a quiet high and quiet low:

Both hex inverters have a quiet high and a quiet low output.

Hex inverters can be powered by 3.3V or 5V:

The prior oscilloscope shots were created using the 5V input. When using the 3.3V input, the bad circuit showed measurably less power rail collapse when the LDO decoupling capacitor was enabled, increasing the minimum quiet high voltage from 2.8704V to 2.9106V. The good circuit showed little difference when the decoupling capacitor was added to the LDO. This is likely due to the improved filtering of the decoupling capacitor for the good hex inverter due to it being placed closer to the IC.

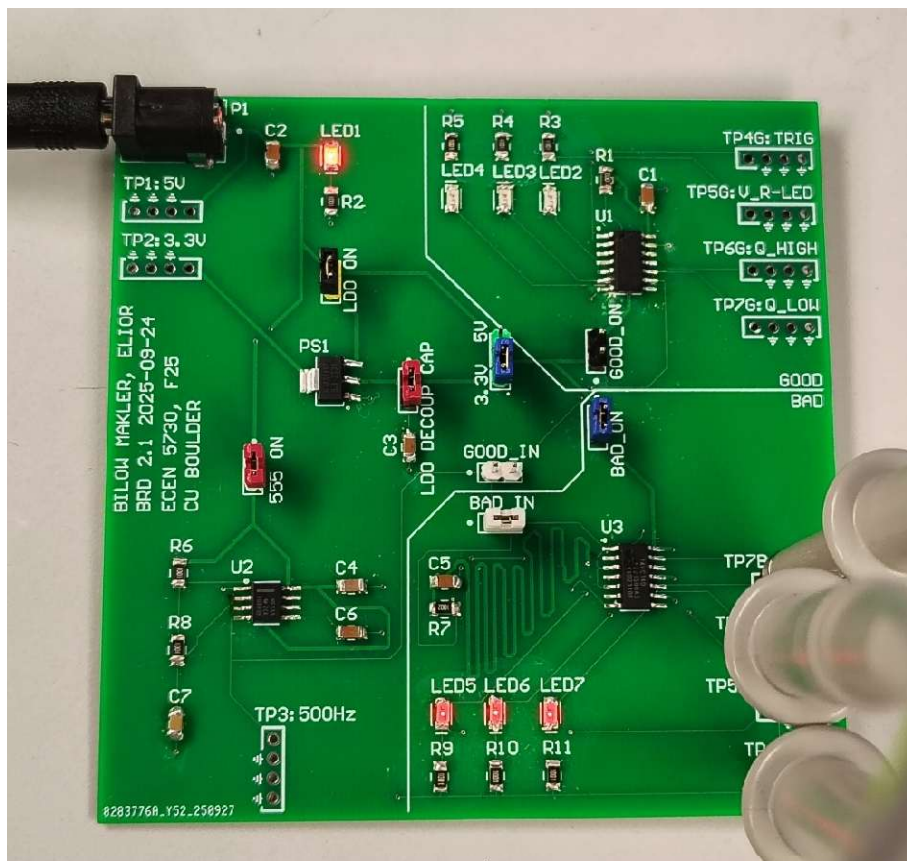


Figure 17: Test configuration for 3.3V LDO decoupling capacitor impact.



Figure 18: Oscilloscope shot of the bad hex inverter while powered by 3.3V without a decoupling capacitor on the LDO (yellow: trigger, green: quiet high, blue: quiet low).

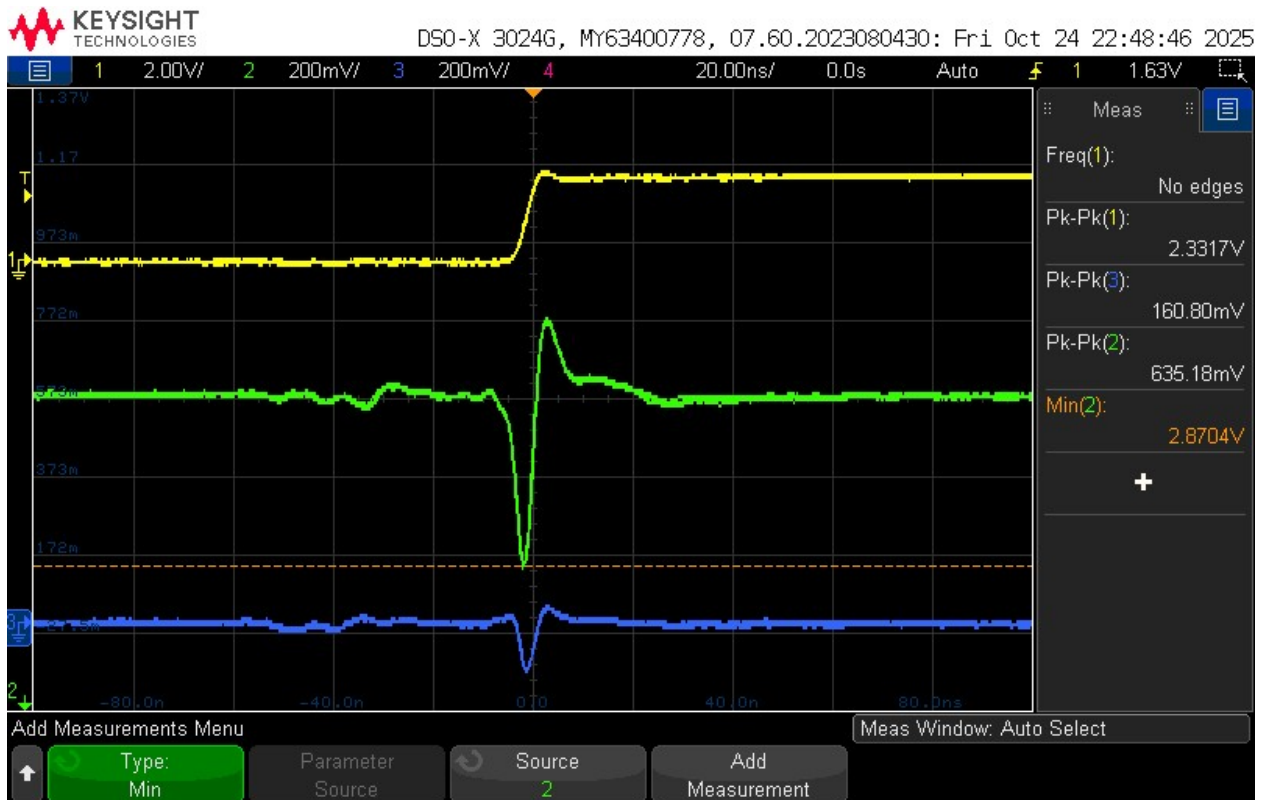


Figure 19: Oscilloscope shot of the bad hex inverter while powered by 3.3V with a decoupling capacitor on the LDO (yellow: trigger, green: quiet high, blue: quiet low).

Analysis of the Project:

Overall, the project was a success because it met the requirements laid out in the POR.

It is clear that the close proximity of the decoupling capacitors to the ICs and the use of a ground plane greatly reduced noise and increased power rail stability and these features will be implemented in my future designs. I also liked the quantity of power on and enable jumpers that I included since it allowed me to isolate problems that I didn't expect like the hex LEDs being powered by the 555 output alone. I was satisfied by the quantity of indicator LEDs which were able to indicate activity in each subcircuit, though I don't think I'll include as many in each subcircuit to make assembly easier.

What didn't work well was the proximity of test points. This made measuring incredibly difficult since the probes were constantly popping out. In the future, I will space out these test points to give the probes more space between one another. Furthermore, the POR test plan was not detailed enough to verify all of the requirements, so a more well developed test plan would be helpful in the future.

There were no hard errors with this board.

The only soft error was the powering of the LEDs by the 555 while the hex inverters were off. I do not think I can change the board to fix this issue; though it could be fixed by including a MOSFET that enables the 555 output feed when the hex inverters are powered on.