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Board 1 Report
ECEN 3730
Spring 2025

1. Plan of Record
   a. Block Diagram

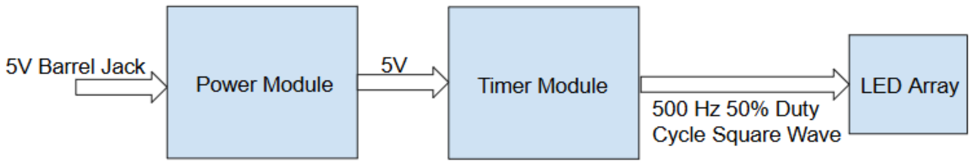


Figure 1: Board 1 block diagram. The power module takes 5V DC as an input from a barrel jack and includes an on/off switch to the rest of the circuit. The timer block is a 555 timer configured as an astable oscillator that outputs a square wave of approximately 500 Hz with a duty cycle about 50%. The LED array includes 4 LEDs each in series with a different current-limiting resistor.

   b. Parts
      i. NE555 Timer: LCSC Part #C7593 (https://www.ti.com/general/docs/suppproductinfo.tsp?distId=10&gotoUrl=https%3A%2F%2Fwww.ti.com%2Flit%2Fgpn%2Fse555)

   c. Requirements
      i. The board will supply 5V from a DC barrel jack to the 555 timer.
      ii. The 555 timer will output a wave with frequency between 300 Hz and 1 kHz and a duty cycle between 40% and 75% (specs from lab manual). To simplify the design and use fewer unique parts, the target values are actually 480 Hz and 67%.
      iii. The square wave will drive 4 LEDs with different current-limiting resistors. The board will allow for a measurement of the current being drawn from the 555 timer.

   d. Test Plan
      i. Test 1: Power
         1. Plug in 5V power cable. Check that LED1 lights up.
         2. Measure voltage at TP1 using the oscilloscope. Verify that it is 5V with tolerance of 10%.
      ii. Test 2: Timer Circuit
         1. Close SW1. Observe output at TP2. Verify that the wave has a frequency of 480 Hz and a duty cycle of 67% (both within tolerances of 5%).
      iii. Test 3: LEDs
         1. Close SW2. Observe LEDs 2-5 light up.
         2. Measure output at TP3. Observe that it has a frequency of 480 Hz and a duty cycle of 67% (both within tolerances of 5%).
         3. Calculate the current drawn from the NE555 and check that it is between 26 and 42 mA (expected range based on 555 timer, LED datasheets and uncertainties).

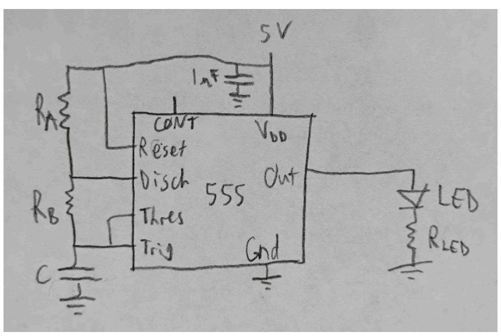
   e. Power Budget

The calculated maximum required power from the supply is 0.2 W. The calculations are shown below, where the maximum current draw of each of the three main modules is estimated separately.

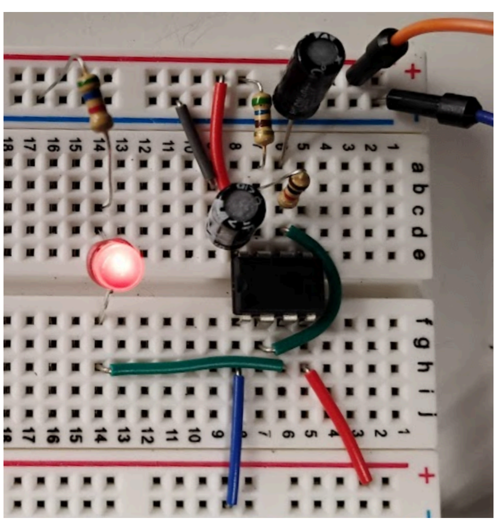
For the timer module, the maximum current is when the capacitor just begins to charge and there is 5 V across 2 kΩ. The only current draw from the power block itself is due to the indicator LED and its series 1 kΩ resistor. For these calculations all LEDs are assumed to have a 1.9 V voltage drop, and the high output voltage from the NE555 is assumed to be 3.3 V (datasheet typical value). The four resistors in the LED array thus have the same voltage across them and can be combined into an equivalent resistance for simplicity.

Module	Equivalent resistance (Ω)	Max voltage across resistance (V)	Max current draw (mA)
Power	1000	3.1	3.1
Timer	2000	5	2.5
LED Array	40.92769441	1.4	34.20666667
			Total circuit max current draw (mA)
			39.80666667
			Power supply requirement (mW)
			199.0333333

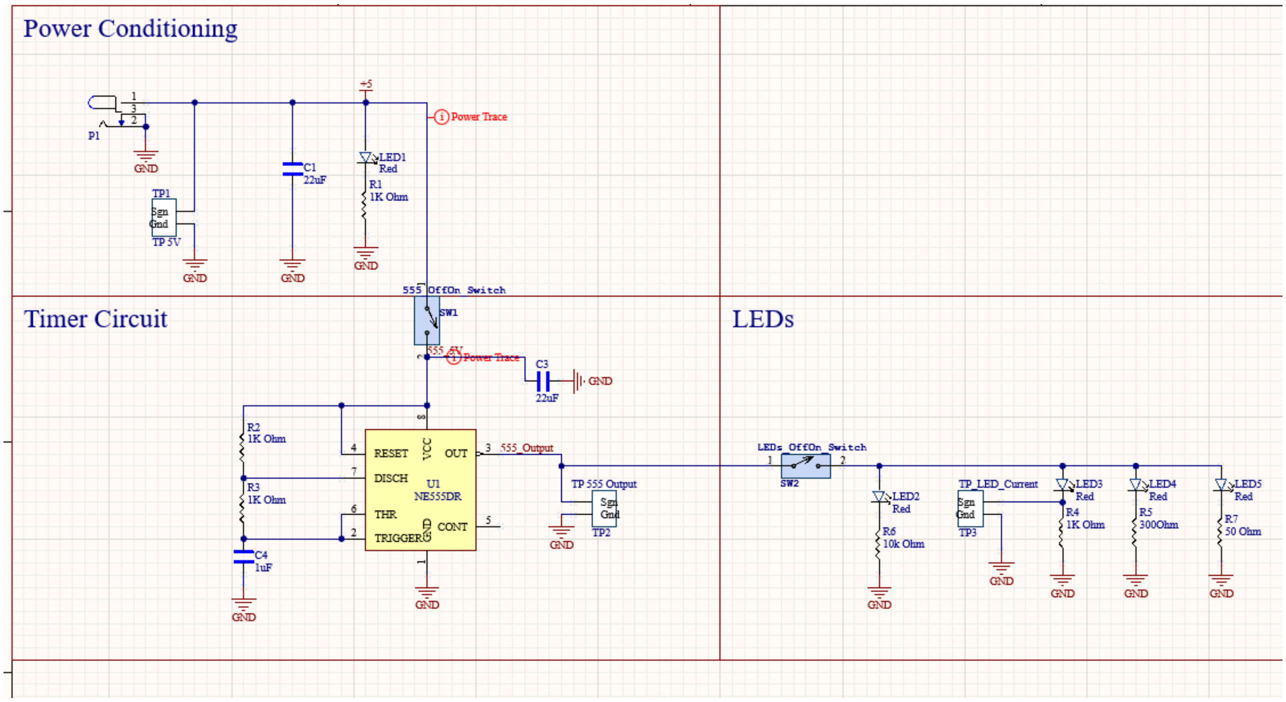
2. Board Progression
    a. Sketch



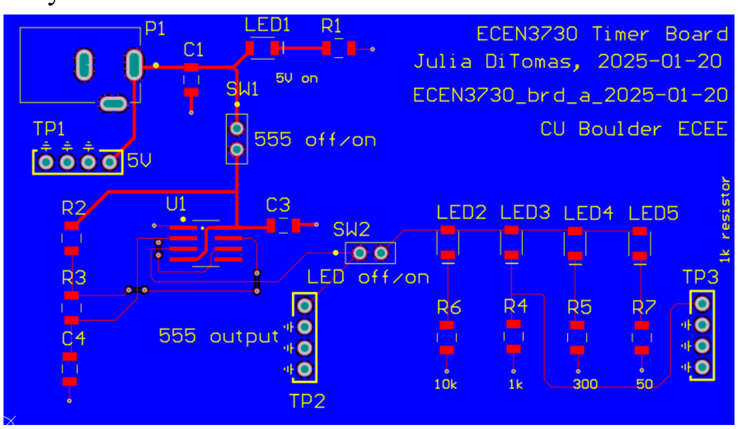
    b. Solderless Breadboard



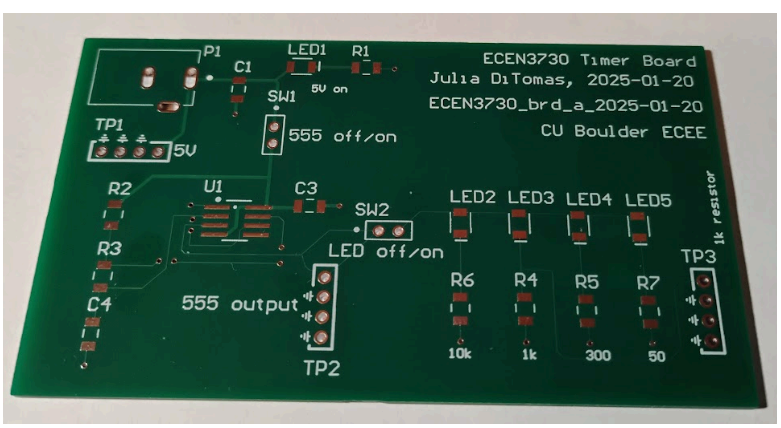
c. Schematic



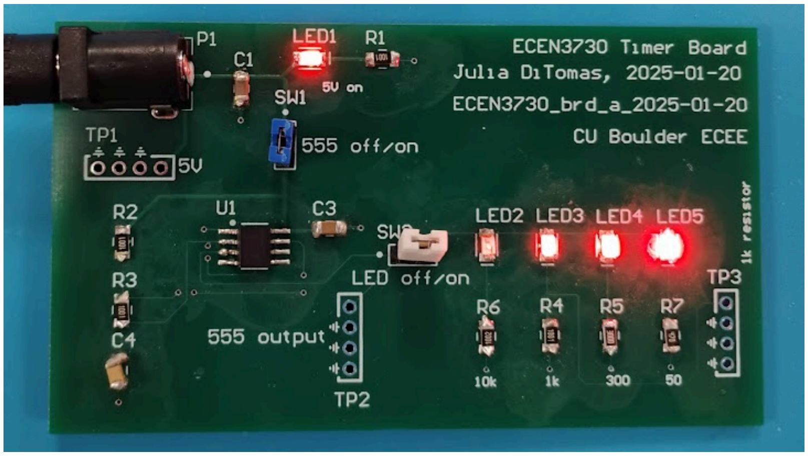
d. Layout



e. Bare Board



f. Assembled Board



3. Board Testing

After assembling the board, I first plugged it in with both switches open, observed that LED1 lit up, and measured the voltage at TP1 to be a constant 5.2 V with the oscilloscope, meaning that the power module test passed. I then closed SW1 and measured the output of the 555 timer. The frequency was 479 Hz and the duty cycle 66%. Thus, the timer module test passed.

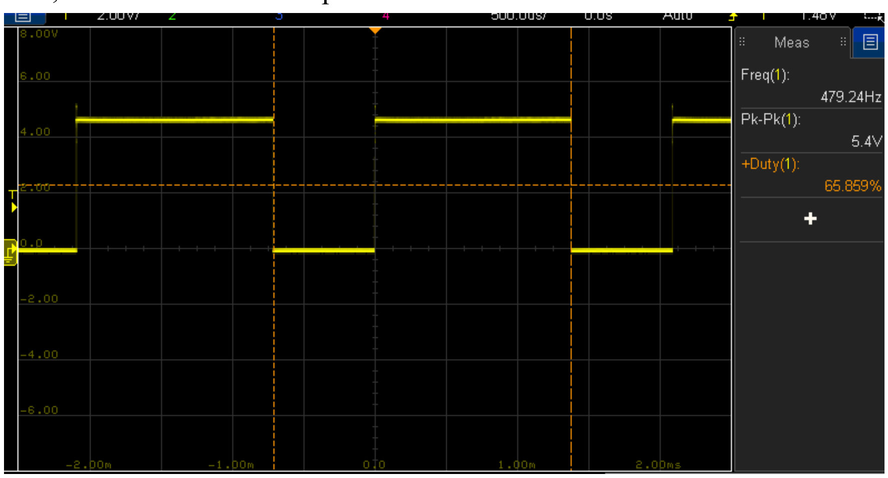


Figure 2: Output of 555 timer when not driving LEDs (SW2 open). Note that although I neglected to include an amplitude measurement, it is about 4.7 V.

I then closed SW2 and watched all four LEDs in the LED array light up to varying brightnesses. I measured the output at TP3, which was a square wave with the same frequency and duty cycle as that measured at TP2. The output voltage from the 555 timer was higher than expected at 3.8 V, which meant that the voltage across the resistors was also higher than expected (1.9 V instead of 1.4 V). The total current drawn from the NE555 when on was $i = \frac{V}{R_{LED,\,eq}} = \frac{1.9\,V}{41\,\Omega} = 46\,mA$ (compared to the predicted value of 34 mA), which was outside of the expected range and thus failed the test. Assuming that each resistor in the LED array had 1.9 V across it, the currents through LEDs 2-5 were 0.19 mA, 1.9 mA, 6.3 mA, and 38 mA respectively. The light from each LED was visible, meaning any of the tested values work for indicator LEDs, but the one in series with 10 kΩ was not as obvious. 1 kΩ provides a nice balance between visibility and low current draw.

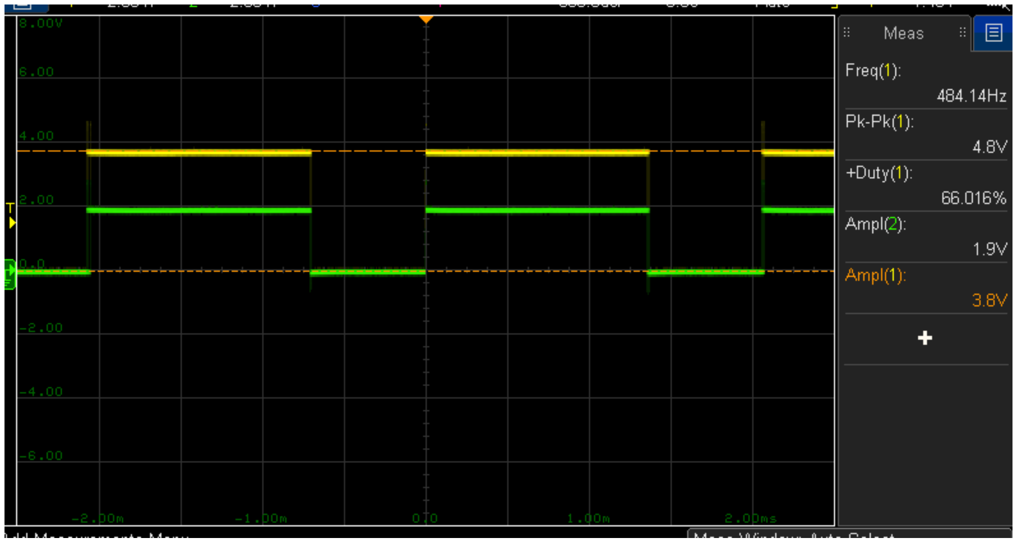


Figure 3: Output of 555 timer (yellow) and voltage across 1 kΩ R4 measured at TP3 (green). Compared to Figure 2, the frequency and duty cycle have both slightly increased but are still within specs.

Finally I found the Thévenin voltage and resistance of the NE555. The Thévenin voltage is 4.7 V from Figure 2. In Figure 3, the high voltage has dropped to 3.8 V, so the Thévenin resistance is $R_T = \frac{4.7-3.8\,V}{0.046\,A} = 19.6\,\Omega$.

4. Conclusions and Lessons

From this project, I learned how to use Altium Designer to create the board schematic, layout, and required files to send to the manufacturer. My board met all of the requirements laid out in the POR and had no hard errors, which was mainly because I could follow Professor Bogatin's instructions throughout the process.

My board, though allowing for a calculation of current draw from the 555 timer, did not match my expected value for this current. Because both datasheets (LED and NE555) specified typical and minimum values, but not the maximums, I decided to calculate the percentage difference between the two given values and use this as the uncertainty for each component. I then added the LED uncertainty and the NE555 uncertainty in quadrature to formulate my expected range of values. I was surprised to find that this didn't work since the uncertainty in the NE555 output voltage (17%) encompasses the actual value ($3.3V * 1.17 = 3.86\,V$). I then realized my mistake was in propagating the errors. Since I was adding independent errors, I should have used absolute errors instead of percentages. I checked and found that this method would have yielded an expected voltage across the resistors between 0.72 V and 2.08 V, and thus a current between 17 mA and 51 mA.

I found that labelling the switches and test points on the silk screen and laying out the board similar to the schematic helped me know what was happening at a glance, so I will continue those habits. The only other thing that I wish I had done differently was label the values of the resistors and capacitor in the timer module. Although I was fairly certain that I knew what they were, I didn't want to make a mistake, so I had to pull up the schematic for reference while soldering. Having values on the silk screen would've made the assembly faster without increasing the potential for error.