University of Colorado - Boulder

ECEN 5730
Practical PCB Design Manufacture — Fall 2024

Board 1 Report - NE555 Timer Driving LEDs

Sam Walker

Samuel Walker

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College of Engineering & Applied Science
UNIVERSITY OF COLORADO BOULDER

Introduction

In this project, we design, assemble, and test a PCB featuring an NE555 timer driving multiple LEDs with different resistances. The goal is to observe the timing characteristics of the NE555 timer, particularly how its output signal is affected by load conditions, as well as to analyze switching noise and rise times. Key components of the project include a power conditioning block, the timer circuit, and the LEDs block.

The purpose of this report is to document the design and testing of the board, including the results obtained through oscilloscope measurements, challenges encountered during assembly, and lessons learned.

Plan of Record (POR)

The Plan of Record (POR) defines what it means for the board to "work." The specific goals and expectations for Board 1 include:

- **Power**: The board operates with a 5V power supply.
- **Signal**: The NE555 timer is expected to generate a square wave with a frequency of 500Hz and a duty cycle of 66%.
- **LED Operation**: Each of the four LEDs should illuminate with varying brightness based on the resistance values, with the brightest LED corresponding to the lowest resistance (47 ohms) and the dimmest to the highest (10k ohms). Current through the LEDs should match calculated expectations.
- **Noise Measurements**: Minimal switching noise should be present on the 5V rail, with appropriate decoupling capacitors used to mitigate noise.

Testing will involve verifying each of these expectations using oscilloscope measurements and other diagnostic tools.

Project Overview

Block Diagram

The block diagram below outlines the main components of the circuit. A 5V power supply powers the NE555 timer, which generates a square wave signal with a frequency of 500Hz and a duty cycle of 66%. This signal drives four LEDs, each with a different resistance.

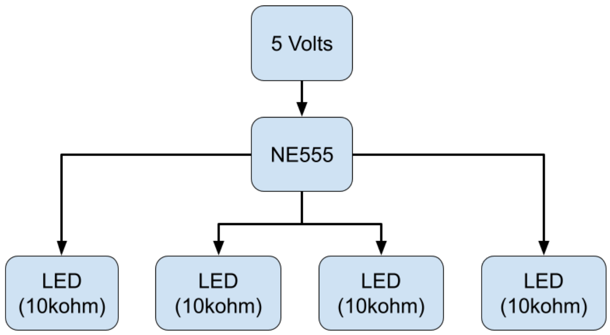

Figure 1: Block Diagram of NE555 Timer Circuit

Schematic in Altium Designer

The schematic captured in Altium Designer is shown below. The design consists of three main blocks: power conditioning, the timer circuit, and the LEDs block. Test points are included to measure key signals such as the 5V source, the NE555 output, and the current through each resistor connected to the LEDs.

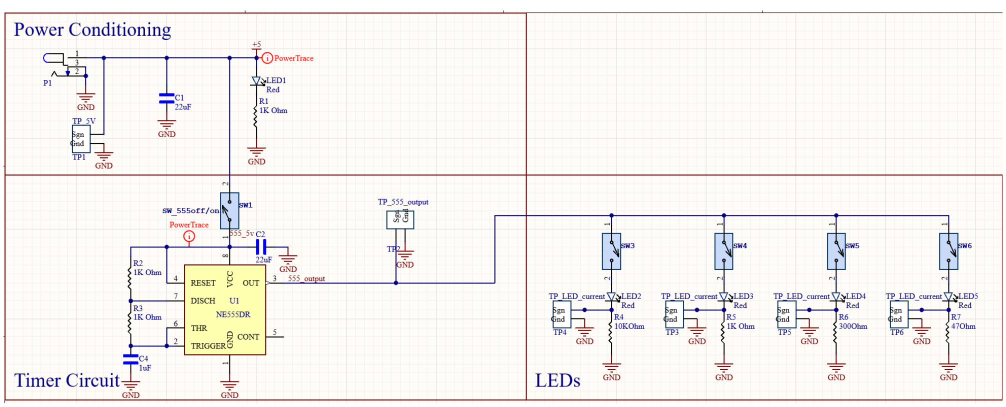

Figure 2: Altium Schematic of the NE555 Timer Circuit

PCB Layout

The layout was designed in Altium, ensuring that each block had its own section on the board for ease of debugging. Power conditioning is located at the top left, and the LEDs are placed at the bottom right. The board was carefully labeled to facilitate testing and assembly.

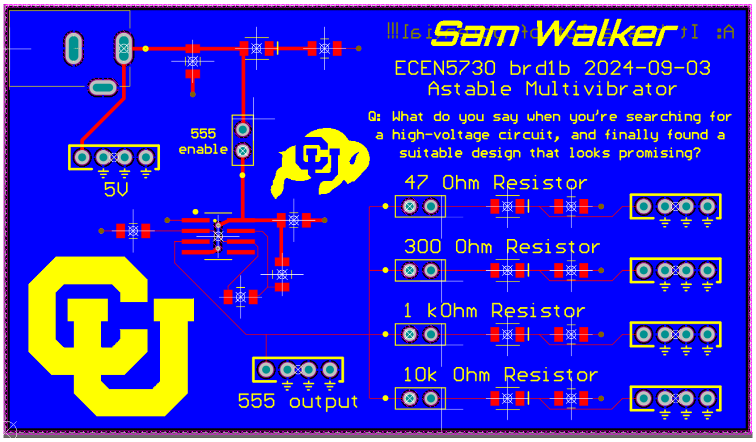

Figure 3: PCB Layout in Altium Designer

Unassembled and Assembled PCB

The unassembled board was received from JLCPCB and is shown below. I then soldered the components, encountering some difficulties with the NE555 IC due to the small pins, which made the process challenging.

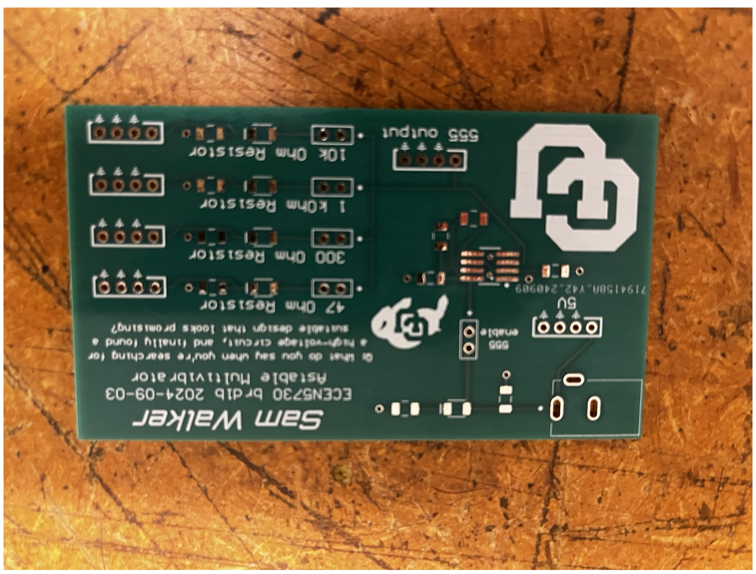

Figure 4: Unassembled PCB from JLCPCB

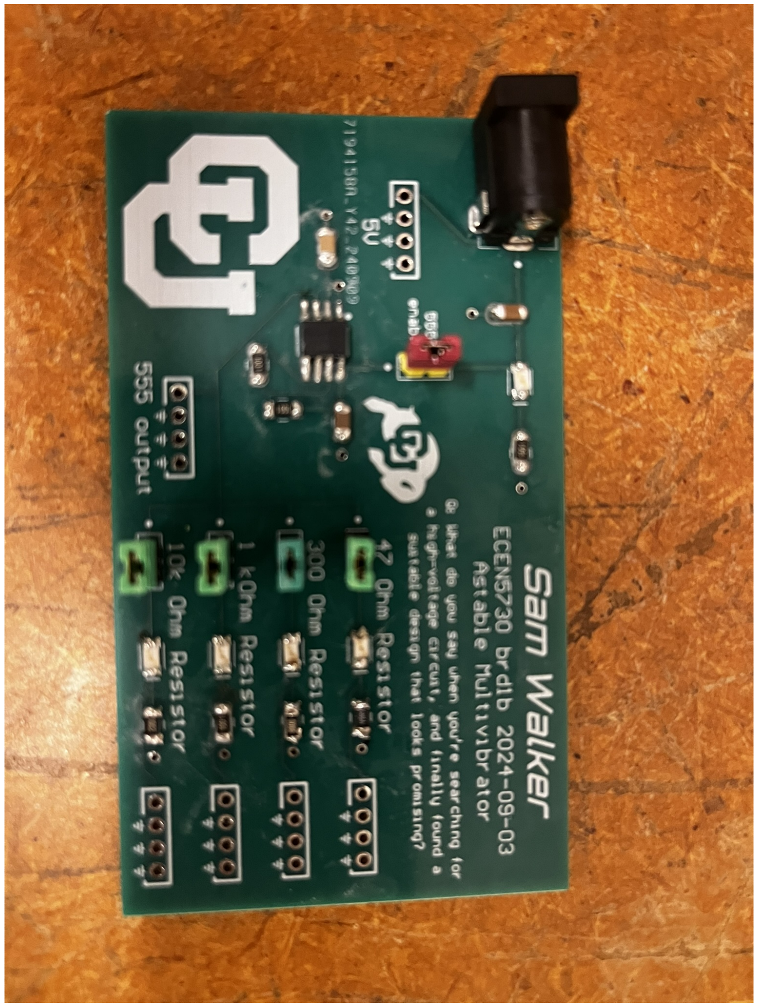

Figure 5: Assembled PCB with Soldered Components

PCB with LEDs On

The final PCB with the LEDs lit up is shown below. The brightness of the LEDs varies as expected based on the different resistances connected to each one. The 47-ohm resistor produces the brightest LED, while the 10k resistor produces the dimmest.

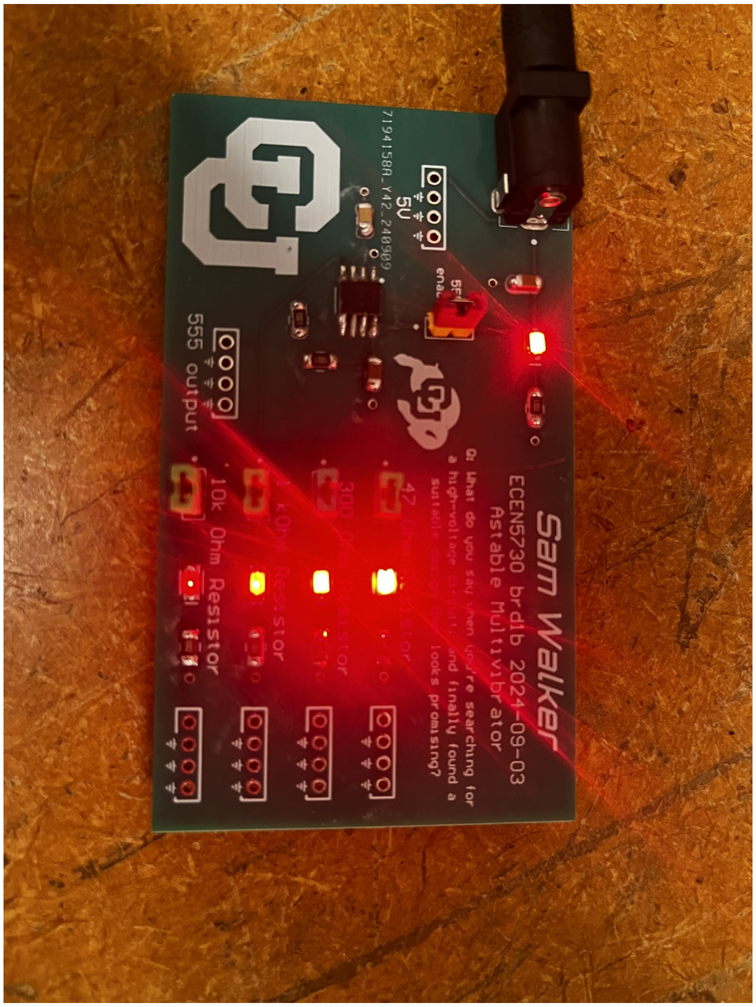

Figure 6: PCB with LEDs Lit

Testing and Measurements

NE555 Timer Output - No Load

The following oscilloscope screenshots show the NE555 timer's output when no load (LEDs) is connected. The amplitude reaches approximately 4.5V, and the rise time is 91ns. The duty cycle is measured at 66.2%, and the frequency is 515Hz. The period graph shows the square wave, while the rise graph zooms in on the rise time.

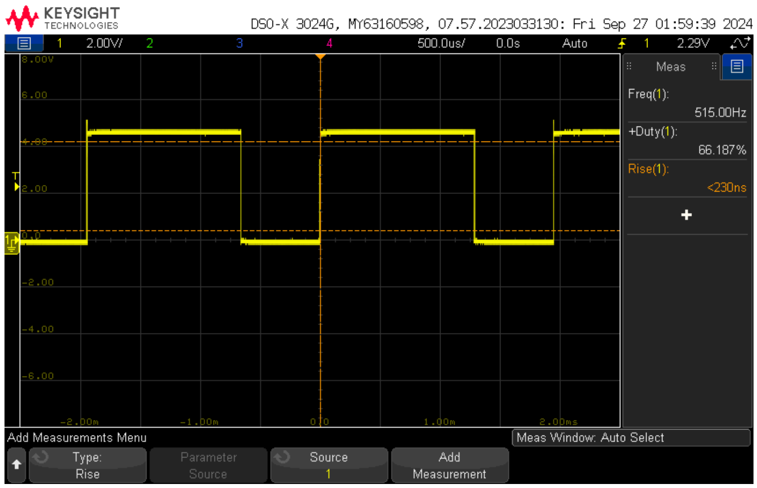

Figure 7: No Load - Period

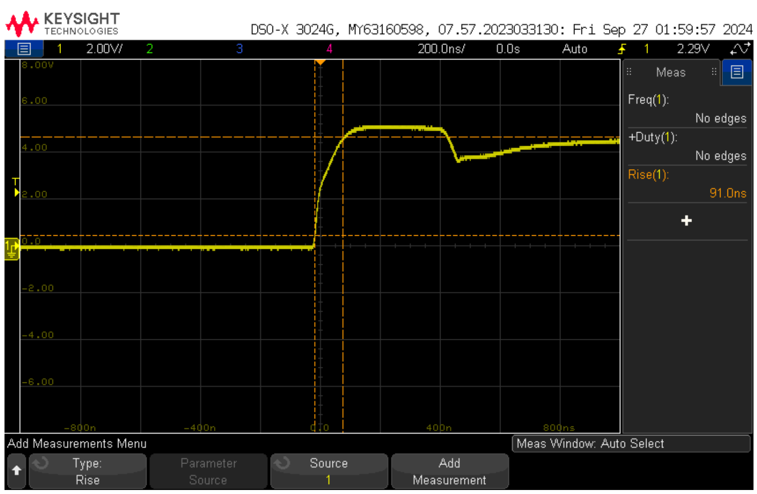

Figure 8: No Load - Rise Time

Analysis of No Load

The amplitude and rise time values observed are as expected for a signal without any load. The 4.5V amplitude closely matches the expected 5V signal from the NE555 timer, and the rise time of 91ns is within acceptable limits for this configuration.

NE555 Timer Output - Loaded

When the LEDs are connected, the amplitude drops to about 3.75V, and the rise time decreases to 53.6ns. The duty cycle remains at 66.1%, and the frequency is 518Hz. The decrease in amplitude and faster rise time are likely due to the increased load on the timer, which draws more current and results in a lower maximum voltage.

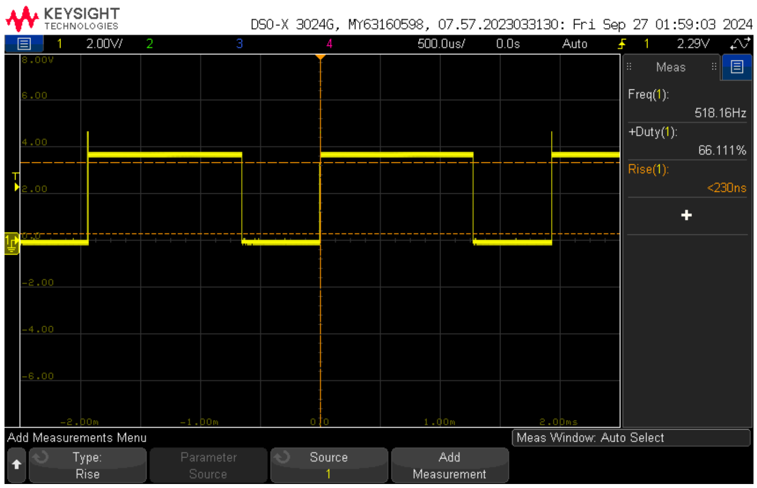

Figure 9: Loaded - Period

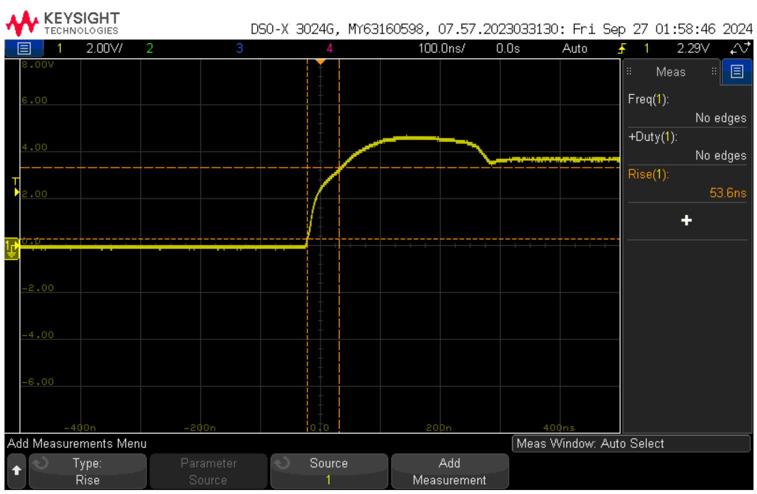

Figure 10: Loaded - Rise Time

Estimation of Current Through Each LED

Using the oscilloscope measurements and assuming the forward voltage drop of the LEDs is approximately 2V, the current through each resistor can be estimated as follows:

$$I = \frac{V_{out} - V_f}{R}$$

For each LED: - 47-ohm resistor:

$$I = \frac{3.75V - 2V}{47\Omega} \approx 37.23\text{mA}$$

- 100-ohm resistor:

$$I = \frac{3.75V - 2V}{100\Omega} \approx 17.5\text{mA}$$

- 1k-ohm resistor:

$$I = \frac{3.75V - 2V}{1k\Omega} \approx 1.75\text{mA}$$

- 10k-ohm resistor:

$$I = \frac{3.75V - 2V}{10k\Omega} \approx 0.175\text{mA}$$

Total Current Draw Through All LEDs

The total current draw with all LEDs connected is the sum of the individual currents:

$$I_{total} = 37.23\text{mA} + 17.5\text{mA} + 1.75\text{mA} + 0.175\text{mA} \approx 56.66\text{mA}$$

Current Through One LED (1k Resistor)

As measured, the current through the LED with a 1k resistor is approximately:

$$I = \frac{3.75V - 2V}{1k\Omega} \approx 1.75\text{mA}$$

Switching Noise

The following screenshots show the minimal switching noise observed on the 5V rail. The noise measures about 15mV, which is a reasonable result given the use of separated traces and decoupling capacitors. However, the period screenshot exhibits unusual shaking artifacts, which could be attributed to measurement errors.

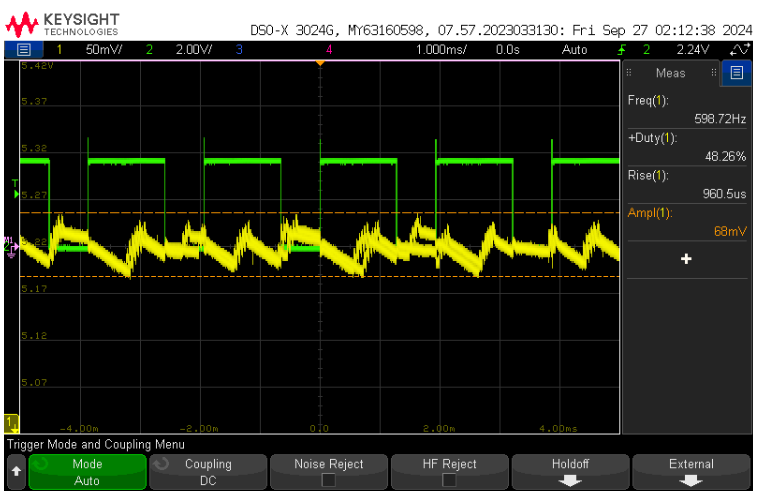

Figure 11: Switching Noise - Period

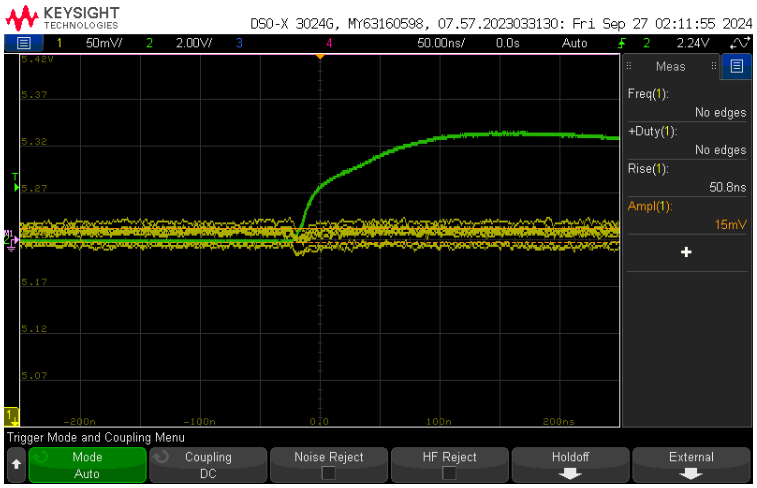

Figure 12: Switching Noise - Rise Time

LED Visibility Recommendation

Based on the visual brightness of the LED with a 1k resistor, which draws approximately 1.75mA, I recommend using a current of around 2mA as the minimum to make the LED visible as an indicator light while saving power. Given the duty cycle is 66

Design and Assembly Reflections

One key success in this project was avoiding significant errors thanks to thorough peer review during the in-class critical design review (CDR). Both soft and hard errors were avoided by cross-checking my design with peers, which ensured no major mistakes during the assembly process.

However, a mistake I made was removing the component designators to make the board look cleaner, which complicated the troubleshooting and verification process. In future designs, I will retain the designators to simplify debugging.

The manual soldering of the NE555 IC was challenging due to its small pins, but this difficulty was mitigated by the use of larger 1206 components elsewhere on the board.

Conclusion

This project demonstrated the importance of proper circuit design, assembly, and measurement techniques in achieving reliable PCB performance. The NE555 timer successfully drove the LEDs, with the expected variations in brightness based on resistor values. The minimal switching noise observed indicates that best design practices, such as decoupling and trace separation, were followed effectively.

Challenges included soldering the NE555 IC and interpreting unusual measurement artifacts, which may require further investigation. Overall, the project provided valuable insights into PCB design, assembly, and testing, with lessons learned that will influence future designs.