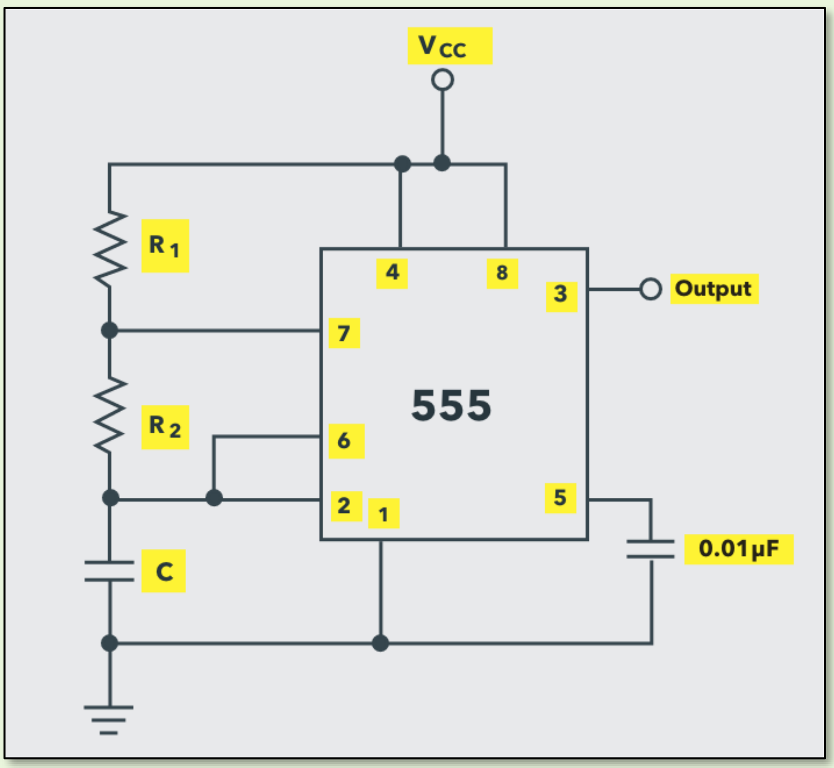
University of Colorado Boulder

ECEN 5730

Practical PCB Design and Manufacture

555 Timer Circuit Astable Multivibrator
BOARD 1
PCB Design



Unmesh Phaterpekar

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☞ ***INTRODUCTION***

The 555-timer circuit, which I have for Board 1, is used to construct an astable multivibrator circuit. It has a duty cycle of about 66% and operates at a frequency of 500 Hz. The timer circuit produces a square wave as its output, which is utilized to toggle the LEDs attached to various loads.

A well-liked and adaptable circuit for producing a continuous series of pulse outputs is the astable multivibrator version of the 555-timer integrated circuit. With this setup, the 555-timer functions as an oscillator and generates a square wave signal without requiring any external triggering. When power is added, the circuit oscillates endlessly in the astable mode. External resistors and a capacitor attached to the integrated circuit (IC) control the oscillations' frequency and duty cycle.

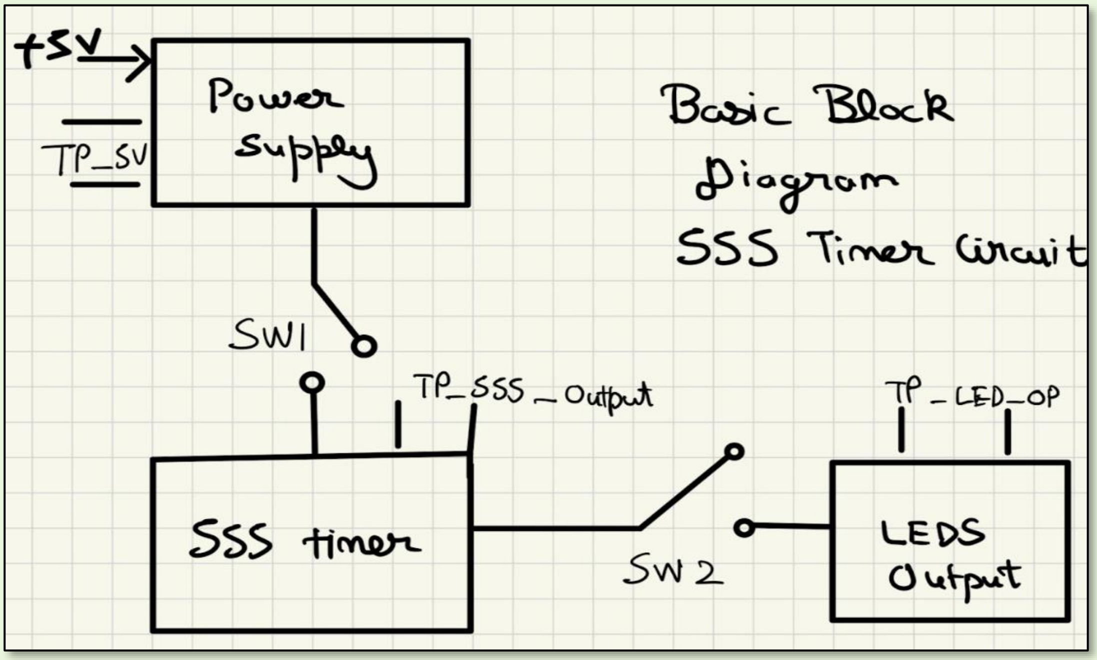
The word "astable" refers to the lack of stable states that define the astable multivibrator mode. A square wave is produced by the circuit's output as it alternates continually between its high and low states. By adjusting the values of the resistors (Designated as R1 and R2) and the capacitor (C), the wave's frequency is changed, offering versatility for a variety of applications such tone production, LED flashers, pulse generation, digital clock signals, and much more. This mode of the 555 timer is highly valued for its dependability, simplicity, and ease of design, which makes it a mainstay in both professional and amateur applications.

☞ ***PLAN OF RECORD***

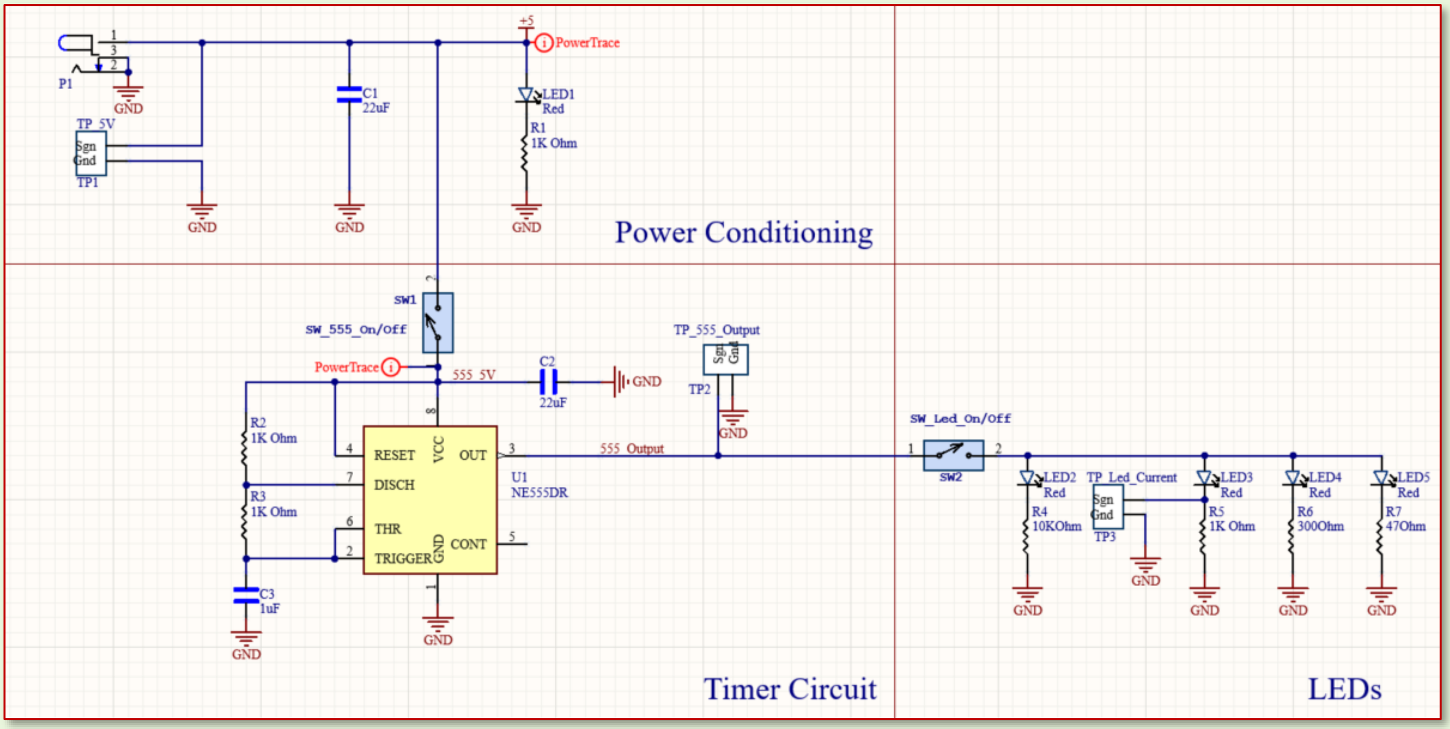
The plan of record for building my Board 1 is as follows:

1. To power up the board, an external 5 V AC to DC charger and power plug are used.
2. The electronics and chips of a 555 timer are intended for approximately 500 Hz and 60% duty cycle.
3. Utilize parts from the library to allow for manual board assembly.
4. Series resistors of 10k, 1k, 300, and 50 ohms are used to connect four LEDs. The moment power is applied, these will activate.
5. To enable debugging, utilize isolation switches, test points, and indicator lights.
6. The architecture includes test points to detect the current flowing through the 1000 Ohm LED, the 555-output voltage, and the 5 V input rail.
7. The calculation of the LEDs' current is made.

☞ ROUGH SKETCH OF SKEMATIC



☞ SKEMATIC CAPTURE ON ALTIUM



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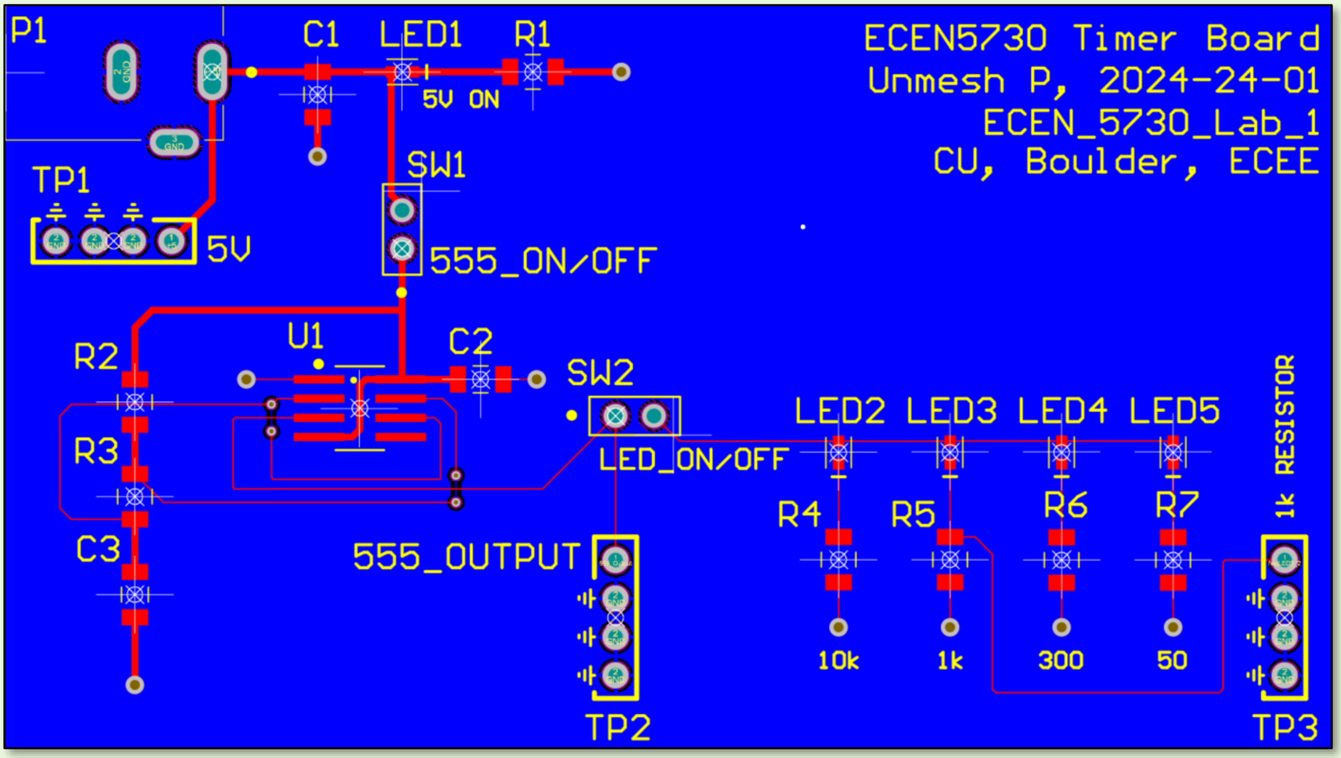
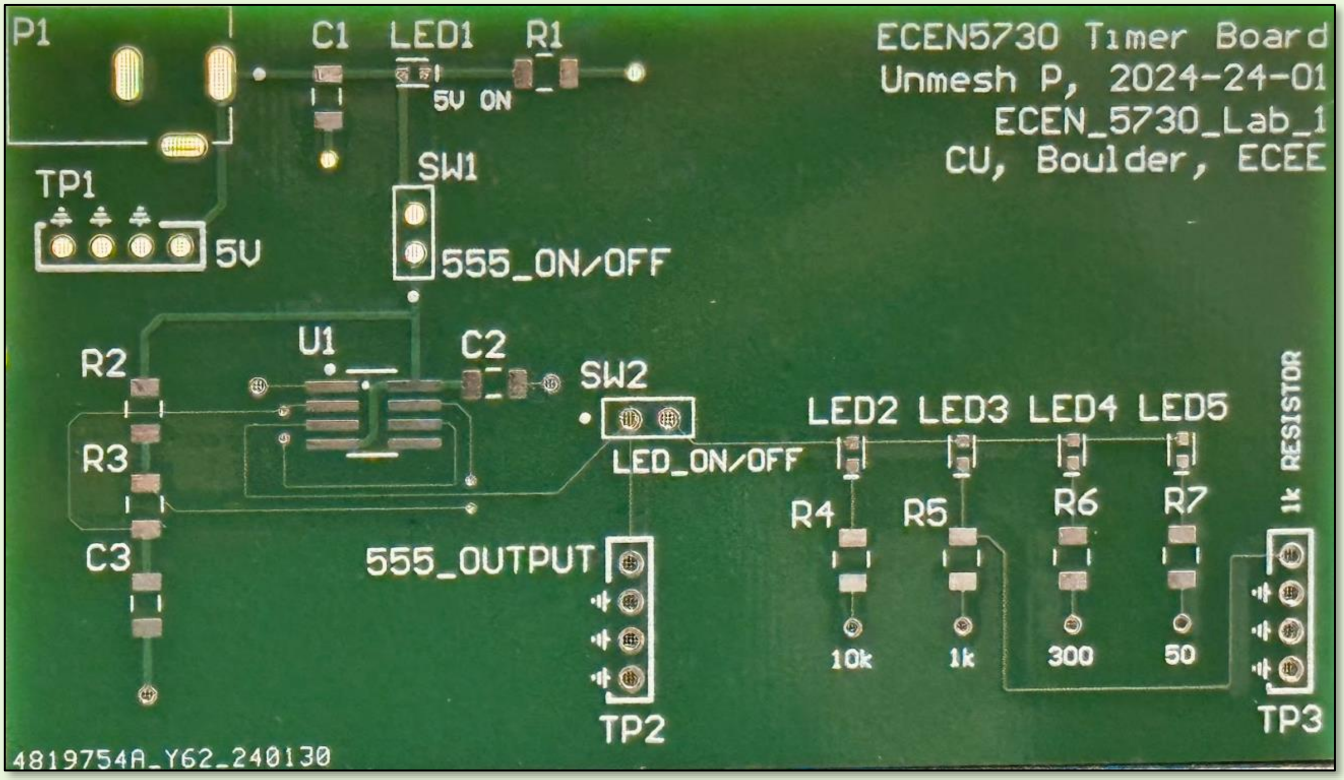
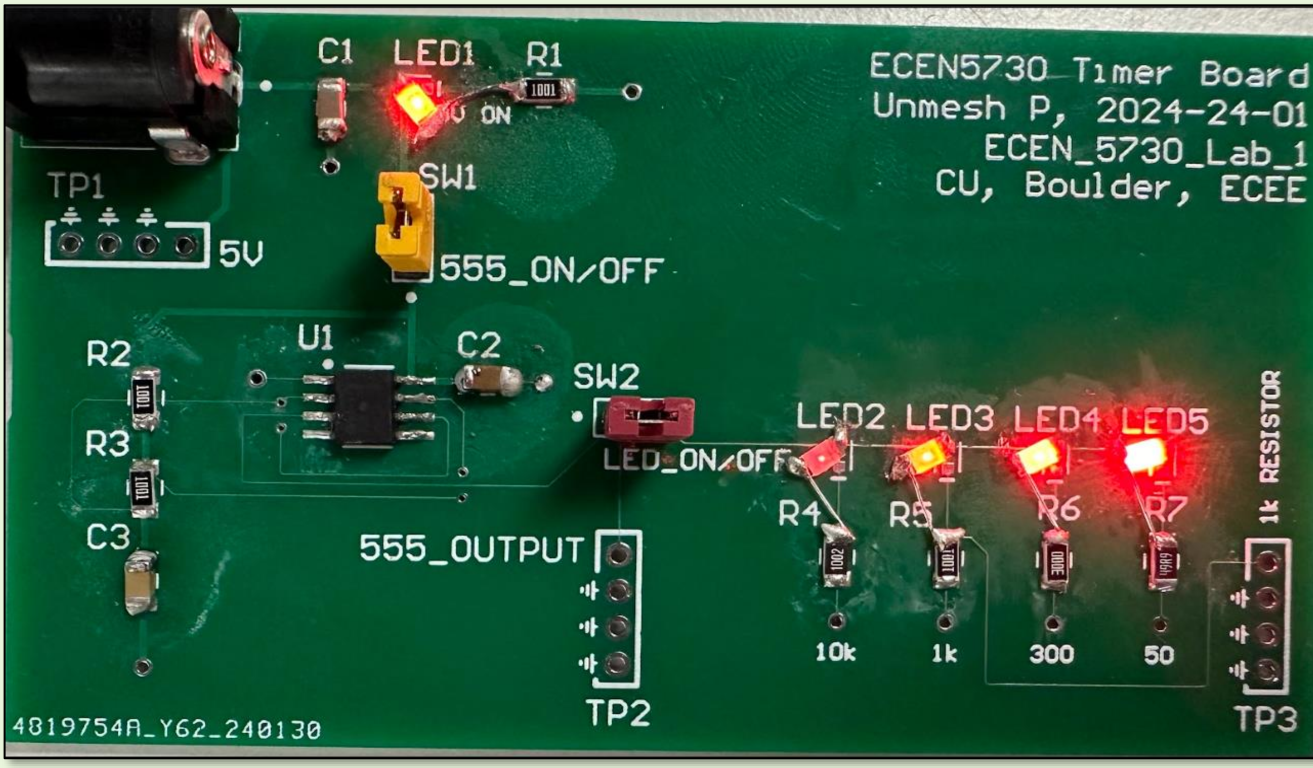
☞ *BOARD LAYOUT ON ALTIUM*



☞ *UNASSEMBLED BOARD PICTURE*



ASSEMBLED WORKING BOARD



CALCULATIONS

$$\text{Time High } (T_1) = 0.693 \times (R_1 + R_2) \times C_1 = 1.386 \text{ ms}$$

$$\text{Time Low } (T_2) = 0.693 \times R_2 \times C_1 = 0.693 \text{ ms}$$

$$\text{Time Period } (T) = 0.693 \times (R_1 + 2R_2) \times C_1 = 2.079 \text{ ms}$$

$$\text{Frequency } (F) = \frac{1.44}{(R_1 + 2R_2) \times C_1} = 481 \text{ Hz}$$

$$\text{Duty cycle} = \frac{R_1 + R_2}{(R_1 + 2R_2)} \times 100 = 66.67\%$$

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☞ ***WHAT WORKED***

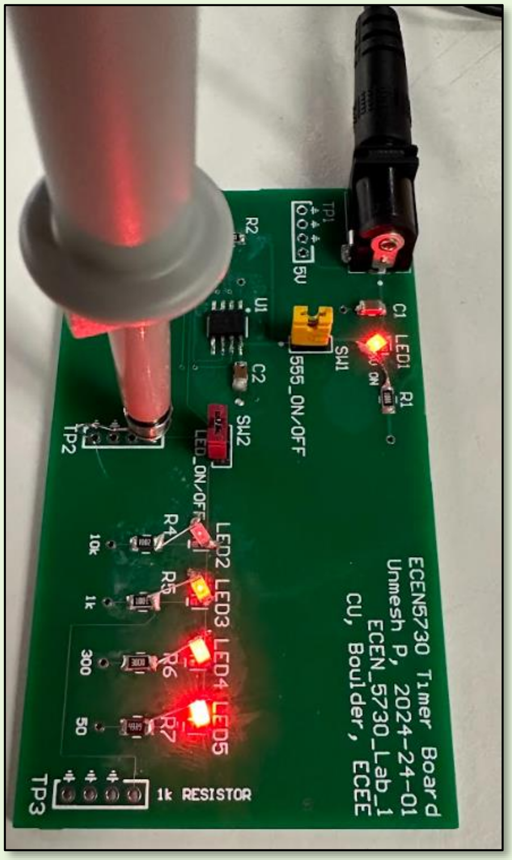

Fig: Testing the 555 timer output

We know that our board is working properly if we see the following outputs:

1. The LED1 must turn ON and a voltage of 5V must be seen at the 5V rail test point for the board to be in a functional state.
2. The output from pin 3 ought to be visible through the second test point once Vcc and the 555 timers are connected.
3. The LEDs light on after being connected to resistors (Load).

   After checking the output at the test point as shown in the given figure, we get a proper square wave at the output of the timer circuit with a duty cycle of approximately 66%.

   The figures given below show the difference between peak voltages when the 555 timer circuit is connected to a load and when there is no load connection at the output.

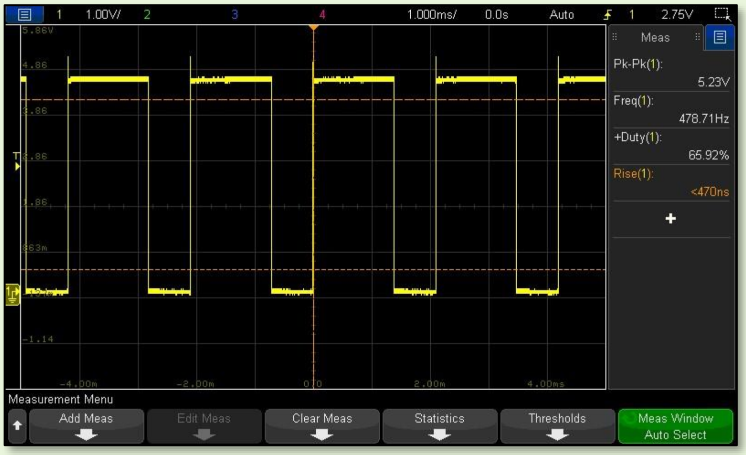

Fig: Output without load

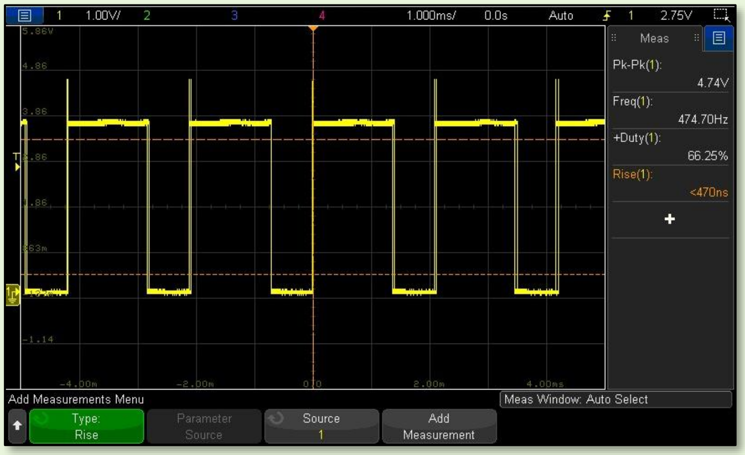

Fig: Output with load

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1. The load pulling current from the output of a 555 timer can result in a voltage drop, which is the main reason for the variation in peak voltage between when the output is connected to a load and when it is not.
2. This is because the output transistor of the 555 timer cannot drive loads with perfect efficiency due to its finite output impedance. Connecting a load improves the current flow from the output, particularly if the load has a low resistance. Ohm's Law states that a voltage drop results from the internal resistance of the 555 timer's output stage as well as any resistance in the PCB traces or connections (V = IR).
3. Consequently, a lower peak voltage is seen at the load because a greater voltage drop across the output stage results from a higher current need for the load.

Fig: Rise Time for Output without load

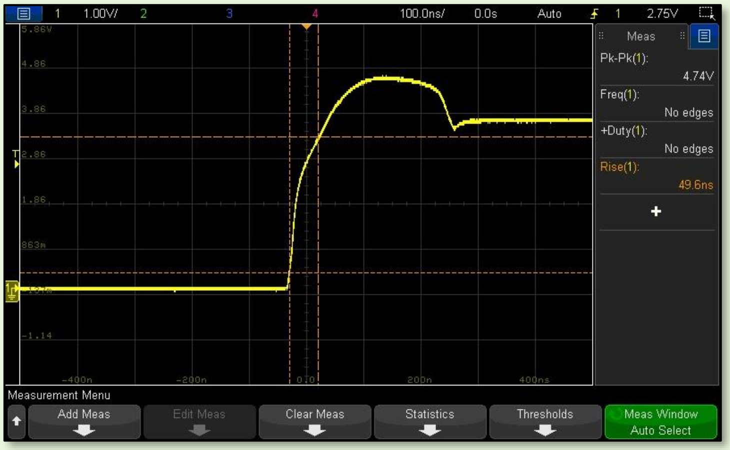

Fig: Rise Time for Output with load

The resistance and capacitance of the load are what cause the rise time difference between the output of a 555 timer with and without a load connected. The 555 timer's restricted current output capabilities means that a load will demand more current, which could slow down the voltage increase. The rising time is further slowed down by the capacitance that loads frequently have, which needs to be charged. In other words, the characteristics of the load delay the output voltage's peak.

THEVENIN'S RESISTANCE

Voltage without load (V_{th}) = 5.23V

Voltage with load connected (V_L) = 4.74V

Thevenin's resistance

$$R_{th} = R_l \, (V_{th} - V_L) / V_L$$
$$= 300 \, (5.23 - 4.74) / 4.74$$
$$= 31.01 \Omega$$

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☞ *BEST DESIGN PRACTICES*

In my 555-timer astable multivibrator PCB design, I have implemented several best practices to enhance performance and reliability:

1. **Stable Power Supply:** To reduce voltage fluctuations, I made sure the power supply was clean and stable.
2. **Decoupling Capacitor:** To filter out noise, I put a 1 µF ceramic capacitor near the 555 timer's VCC and GND pins.
3. **Short Trace Lengths:** To minimize noise and interference, I constructed the PCB with short traces connecting key components.
4. **Ground Plane:** To reduce ground loop interference and enhance signal integrity, I included a ground plane.
5. **Test Points:** To make troubleshooting and verification easier, I included test points for important signals like the output and power supply.
6. **Component Spacing:** To avoid short circuits and to accommodate thermal expansion, I made sure that there was enough space between components.

☞ *EXPECTED VS MEASURED VALUES*

Parameters	**Expected**	**Measured**
Frequency	500Hz	478.70Hz
Duty Cycle	60-70%	66.25%
Rise Time	30-70ns	49.6ns

☞ *MISTAKES MADE*

Being new to PCB design and closely following the instructional video, I encountered a slight setback that resulted in additional time spent on board assembly. Specifically, I mistakenly used 0603 parts for the LEDs instead of the intended 1206 parts in the PCB design. Unfortunately, this error went unnoticed until after the board had been dispatched for production.

There weren't any hard errors which I had to encounter. Just using the wrong footprint for the LEDs.

I solved this problem using wires. I simply soldered one side of the LED to the thermal relief on the board and the other side was connected using small thin wires.

I was lucky not to face any soft errors as well and my outputs matched my calculations as shown in the table given above.

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☞ ANALYSIS AND EFFECTIVE LEARNINGS

1. Every component of the circuit functioned.
2. The hand assembled board and the factory assembled board did not differ significantly.
3. Switching noise is decreased by the slow 555 timer's (NE555DR) delayed switching. Switching noise is influenced by the IC's switching speed.
4. Power rail switching noise is reduced by the proximity of the decoupling capacitor to the IC.

☞ CONCLUSION

In conclusion, a sturdy and dependable circuit may be created by carefully planning the layout, load management, power stability, noise reduction, testability, safety, and intelligent component selection when developing a 555 timer astable multivibrator PCB. These procedures not only improve the performance of the design but also provide important lessons for other electronic projects in the future, highlighting the significance of careful planning and design in obtaining effective results in PCB Designing.