ECEN 3730-
PCB Design,
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Lab 2 Report: SBB-build 555 timer

Objective

The goal is to build a 555 astable vibrator circuit operating at about 500 Hz and about 50% duty cycle. However, in this case, we do not have extreme flexibility in design. Therefore, the exact operating frequency is not important, as long as it is between 300 Hz and 1 kHz. Similarly, the duty cycle is not critical as long as it falls within 40% and 75%.

By using two different 555 chips, applying an equal load to both, and then measuring both the rise time of the waveform and the amplitude of the IC's output voltage, we can compare the results of both 555 timers in order to analyze which has better performance and will be more suitable for our future PCB designs.

Rather than implementing & testing several different designs, I decided to use the one provided in the 555 data sheet, with the intention of solving for component values, implementing it, and then evaluating whether or not it accomplishes the task. If it doesn't, then I would switch to another reference design.

Component List

- Oscilloscope
- Waveform generator
- SBB and basic circuit components
- NE555 timer chip
- TLC555 timer chip

Step 0: Solve for R and C.

To solve for the resistor and capacitor values for the astable vibrator circuit, I once again followed the equations provided on the data sheet.

$$\text{period} = t_H + t_L = 0.693(R_A + 2R_B)C$$

$$\text{frequency} \approx \frac{1.44}{(R_A + 2R_B)C}$$

$$\text{Output driver duty cycle} = \frac{t_L}{t_H + t_L} = \frac{R_B}{R_A + 2R_B}$$

$$\text{Output waveform duty cycle} = \frac{t_H}{t_H + t_L} = 1 - \frac{R_B}{R_A + 2R_B}$$

$$\text{Low-to-high ratio} = \frac{t_L}{t_H} = \frac{R_B}{R_A + R_B}$$

Choosing a capacitor equal to $1\mu F$, I then solved for Ra and Rb by setting them equal to each other, and plugging in to the frequency equation.

$$f = \frac{1.44}{(Ra+2Rb)C}$$

$$Ra + 2Rb = \frac{1.44}{fC} = \frac{1.44}{(500\ Hz)(1*10^{-6}\ F)} = 2880\ \Omega$$

$$Ra + 2Rb = 2880\ \Omega \quad \Leftrightarrow \quad Ra = Rb = 960\ \Omega$$

Then, plugging into duty cycle equation:

$$Duty\ Cycle\ (\%) = 1 - \frac{Rb}{Ra + 2Rb} = 0.5 \quad (for\ 50\%\ cycle)$$

$$Duty\ Cycle\ (\%) = 1 - \frac{9.6}{9.6 + 2(9.6)} = 1 - 0.333 = 0.666$$

With values $Ra = Rb = 960\ \Omega$, we can achieve a frequency close to 500 Hz with a 66.66% duty cycle.

I did not have a 960Ω resistor in my kit, so I proceeded forward using two 1kΩ resistors.

Step 1: Build of the 555 timer with the TLC555

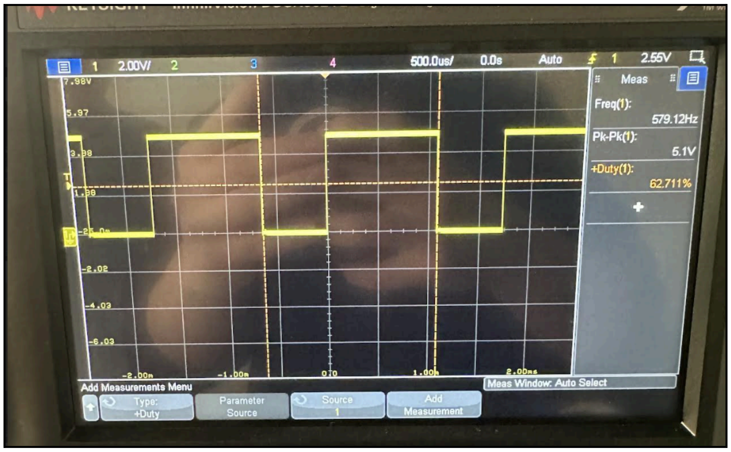

Figure 1:
With the newer 555 timer, the output oscillates at ~580 Hz with a ~60% Duty cycle.

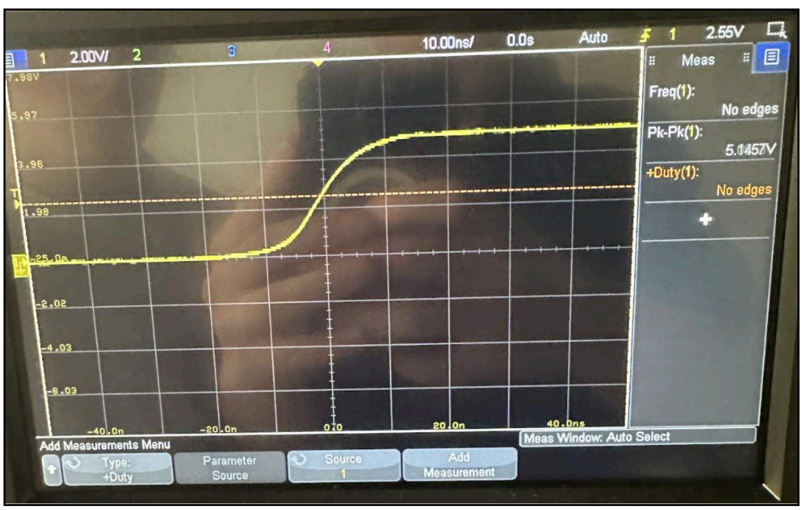

Figure 2:
The output of the timer has a neat rising edge, with a rise time of about ~18ns.

Step 2: Build the 555 timer with the older 555 timer, NE555

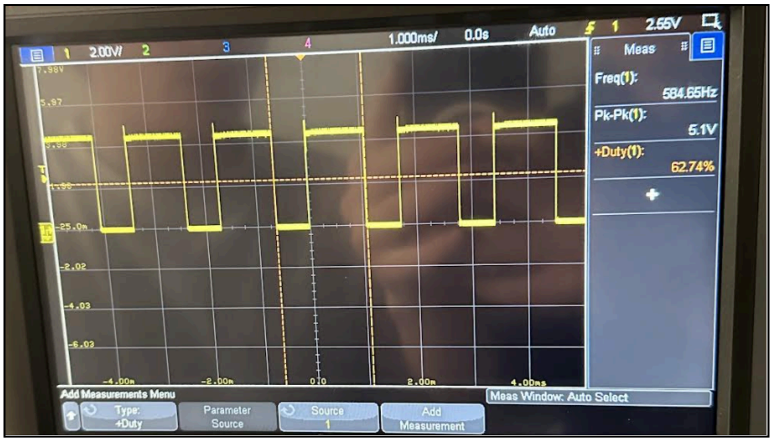

Figure 3:
Frequency of ~580 Hz and a duty cycle of ~60% with NE555 timer

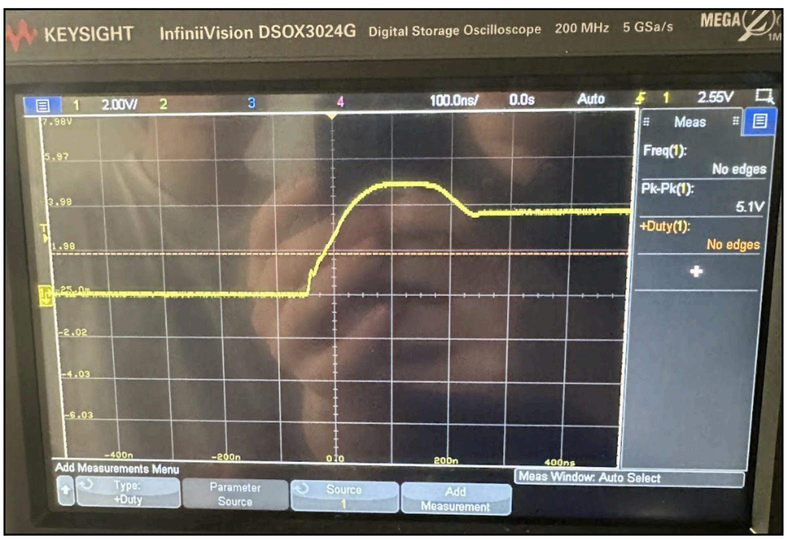

Figure 4:
Waveform exhibits a noticeably slower edge, with a rise time of ~100ns.

I initially estimated the rise time measurements visually, then subsequently verified my measurements using the cursor tool on the scope. In this lab, the automatic rise/fall time measurement on the oscilloscope did not provide accurate results.

Step 3: Now with the circuit working as intended, I drove an LED with a 1k series resistor.

Figure 5:
Shows the rising edge of the TL555 timer (new) with the 1k series resistor added

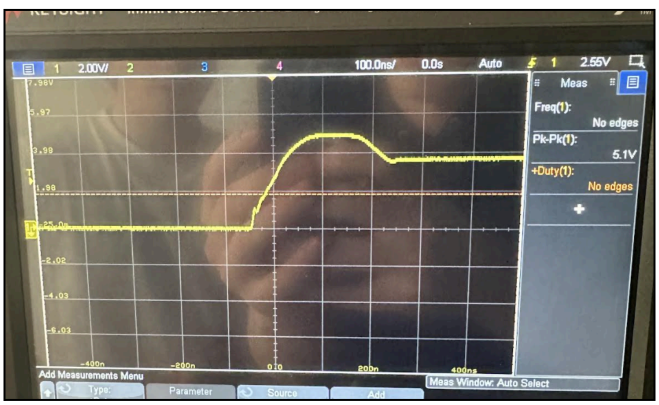

Figure 6:
Shows the rising edge of the NE555 timer (old) with the 1k series resistor added

As seen, after adding the LED to the circuit, the output voltage drops 0.4 V with the TL555 chip. Comparatively, the output voltage drops 0.1 V with use of the older NE555 timer.

The NE555 timer experiences a smaller voltage drop when attached to the same 1k resistor and LED. Hence, it is a better timer for circuits that draw a larger current, compared to the TLC555 that showcases a significant drop in output voltage when connected to a current-drawing load.

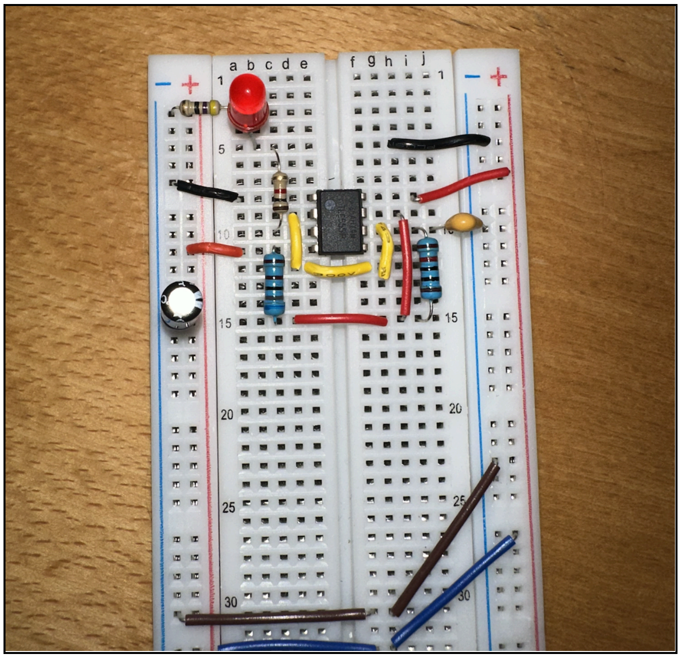

Figure 7: Shows the complete circuit build on the SBB.

<u>Conclusion:</u>

- Though the TLC555 showcases a significantly better rise/fall time in its output waveform, it is unsuitable for circuits that draw a load. It experiences a large voltage loss when a current is drawn.
- The NE555 timer has a slow rise/fall time, but works significantly better than the TLC555 when connected to a current-drawing load.
- Therefore, it is extremely important to consider design trade offs. Not only between what parts are accessible, but also between what parts would be more useful for a specific task. In this case, each timer has a pro and a con, so it is up to the purpose of the design to decide which would be better.
- Another key learning is the importance of being able to search through datasheets in order to find necessary information, equations, and component references.
- Understanding the importance of rule #9 (making an educated prediction before measurement is taken) as well as the methods and tools to measure values on the oscilloscope are extremely important.
- It's always important to check each individual component while debugging. Oftentimes, it's an easy fix that can go undetected by the pair of eyes who built it. I could have saved myself over an hour if I had methodically troubleshooted the circuit piece by piece, rather than completely rebuilding it when I felt stuck. As we move to more complex builds, the latter won't be an option.
- Overall, this lab is important in revisiting basic debugging and circuit building techniques. More specifically, it stresses the fact that outputs won't always match calculations, so troubleshooting, double checking, and understanding the true purpose of the circuit (similar to rule #9) are of utmost importance.