555 Timer Mini Project

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The 555 timer IC was originally designed in 1971 by Hans Camenzind and has proved to be an incredibly useful IC with no major changes since its inception almost 50 years ago. Its usefulness comes from its broad applicability in a vast number of fields: from toys, spacecraft, and hobbyist electronics. The 555 timer can operate in two different modes: astable and monostable. With a monostable, it can act as a 'one-shot' signal, generating a single signal depending on an input. With astable operation, it can be used to create continuous square waves with varying duty cycles and periods. This mini project aims to build my understanding of the 555 timer and datasheets: specifically, using them to understand, build, and modify circuits given a general application or goal. Regarding this specific application, I was curious as to how two timers can operate together to create inverse signals, which could be used in railroad signs, police lights, or pedestrian crossings.

I. Theory

The 555 timer gets its name from the three 5 kilo-ohm resistors voltage divider used in the circuit. A block diagram can be seen below:

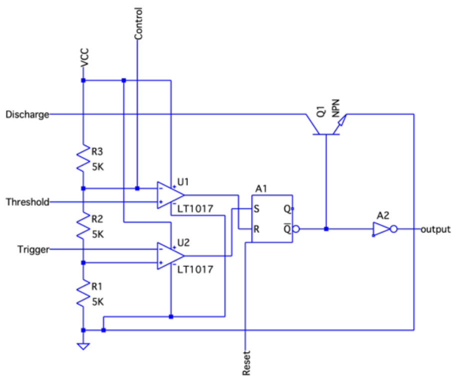

Fig. 1. Block Diagram of a 555 Timer

The basis of this IC is the previously mentioned voltage divider, which divides the voltage into thirds and allows the comparators to use two different reference voltages, one-third and two-thirds, respectively. These two comparators are used to compare the two inputs, trigger and threshold. If the trigger is below than 1/3 of the input voltage, the comparator goes high, and if the threshold is greater than 2/3 of the input voltage, the second comparator goes high. When the trigger comparator (U2 in this diagram) goes high, it causes the Q-bar output to go low, and since the output of the SR Flip Flop is flipped, the resulting output is high. When the threshold comparator (U1 in this diagram) goes high, this resets the SR flip-flop and causes the output from Q bar to be high, and since this signal is inverted, it causes the output to be low.

A. Monostable Operation

In monostable operation, the 555 timer is in a stable low output. When the trigger pin goes below 1/3 VCC, the comparator will output a 1 to the S input of the flip-flop. This causes the Q bar output to go too low and, as a result, the output of the timer to go high.

The time during which the output is high can be found from the equation below:

$$T_{high} = 1.1 \times R \times C$$

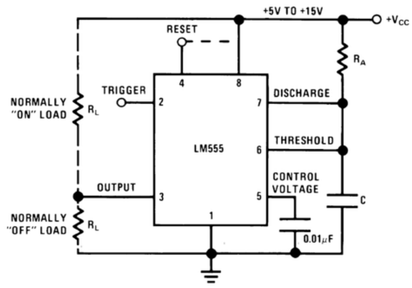

Fig. 2. Example implementation of a monostable 555 timer (source: [1])

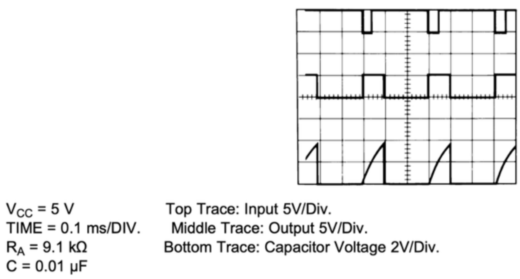

Fig. 3. Waveform output of the above monostable circuit (source: [1])

B. Astable Operation

As previously stated, the 555 timer in astable operation produces square waves at a specified duty cycle and period. This is achieved using an RC circuit with the trigger and threshold pins connected. When the capacitor charges, the output of the timer is high until it reaches the 2/3 VCC limit, which causes the output to go low until the voltage drops to 1/3 VCC, with the cycle continuing.

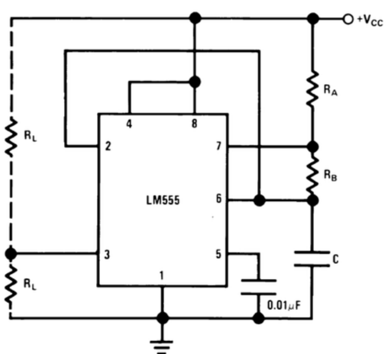

Fig. 4. Example implementation of an astable circuit (source: [1])

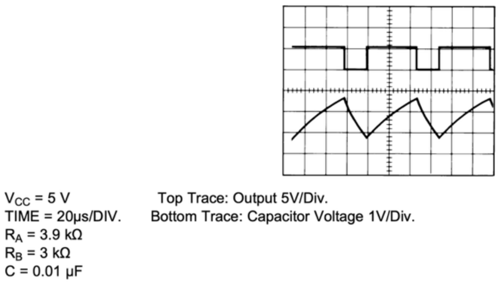

Fig. 5. Waveform output of the above astable circuit (source: [1])

To vary the duty cycle and frequency of the astable circuit, the following equations should be used.

$$T_{high} = 0.693 \times (R_1 + R_2) \times C_1$$

$$T_{low} = 0.693 \times R_2 \times C_1$$

$$T = T_{high} + T_{low} = 0.693 \times (R_1 + 2R_2) \times C_1$$

$$f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2) \times C_1}$$

$$D = \frac{T_{high}}{T} = \frac{R_1 + R_2}{R_1 + 2R_2}$$

II. Experimental Procedure

A. Monostable Mode

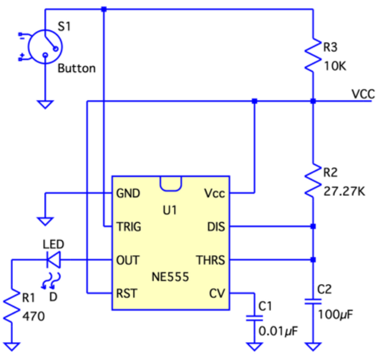

Fig. 6. Circuit Schematic of a monostable implementation with T=3s

1) Parameter Calculations

$$T_{high} = 1.1 \times R \times C$$

$$R = \frac{T_{high}}{1.1 \times C}$$

$$R = \frac{3\ \text{s}}{1.1 \times (100 \times 10^{-6}\ \text{F})}$$

$$R = 27{,}272.7\ \Omega \approx 27.27\ \text{k}\Omega$$

$$T_{high} = 1.1 \times (27{,}000\ \Omega) \times (100 \times 10^{-6}\ \text{F}) = 2.97\ \text{s}$$

Note: To simplify these calculations, we chose a capacitor value of 100uF from the lab kit.

2) Circuit Setup and Procedure

Construct the circuit as seen on the breadboard. Be sure to place the 555 timer IC around the slot in the middle of the breadboard. To ensure an accurate time for the monostable output, you can use two resistors in series to achieve a value close to 27k, such as a 22k resistor in series with a 5k resistor. Once your circuit is set up, apply 5V using a USB power supply and connect your oscilloscope probes to the output pin of the 555 timer.

B. Astable Mode (60% Duty Cycle)

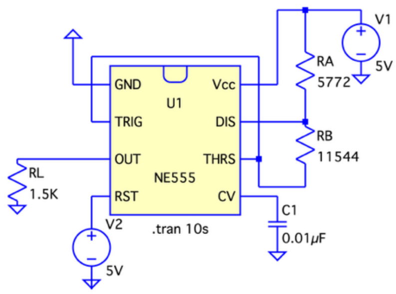

Fig. 7. Circuit Schematic of an astable implementation, 60% duty cycle

1) Parameter calculations

$$\mathrm{T_{high}} = 1.2 \quad \mathrm{T_{low}} = 0.8 \quad C = 100\mu\mathrm{F}$$

$$1.2 = 0.693(R_A + R_B) \times 100\mu\mathrm{F} \quad \rightarrow \quad R_B \approx 11544\Omega$$

$$0.8 = 0.693R_B \times 100\mu\mathrm{F} \quad \rightarrow \quad R_A \approx 5772\Omega$$

2) Circuit setup and procedure

Construct the circuit as seen on your breadboard, being sure to place the 555 timer in the DIP groove. Connect the terminals of the breadboard to the USB power supply, and connect your oscilloscope probes to the output pin of the 555 timer and ground. You may need to use an extra wire to connect them. Once connected to your scope, scale appropriately or use auto scale to capture the signal in a single screen.

III. Application of a 555 Timer

For this project, I have decided to explore the use of two 555 timers to control two sets of LEDs and mimic the flashing light sequence found on police lights and railroad crossings.

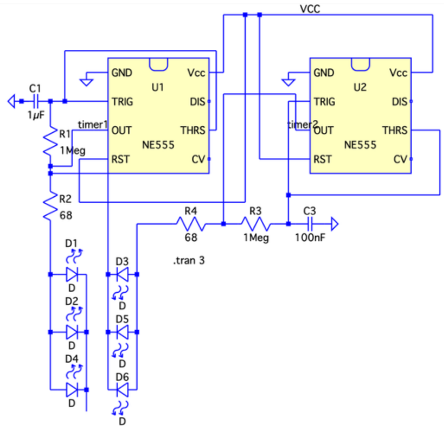

Fig. 8. Circuit Schematic of a flashing LED circuit

This circuit. Consists of two astable 555 timers generating continuous square waves with a duty cycle and frequency determined by the external network of capacitors and resistors. When the circuit starts, the capacitor begins to charge, which sets it below the 1/3 VCC threshold for the trigger pin, which drives the output to high. When the capacitor reaches the upper threshold of 2/3 VCC, the output then transitions to low. The discharge pin then allows the capacitor to discharge and repeat the cycle. Using two parallel 555 timers allows us to connect the LEDs in a way in which they are only on when the other is off.

IV. Results and Discussion

A. Monostable Mode

	Theoretical	Simulated	Experimental
Output period [s]	3	3	2.9

PERCENT ERROR: 2.9%

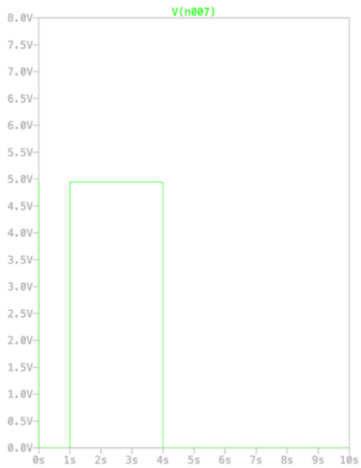

Fig. 9. Simulation Graph

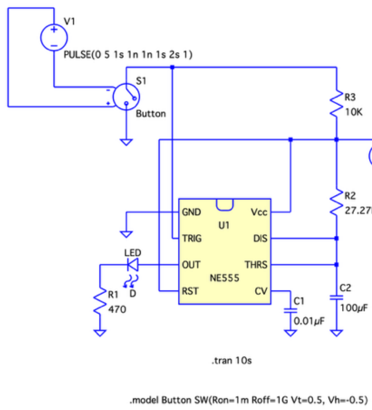

Fig. 10. Simulated circuit

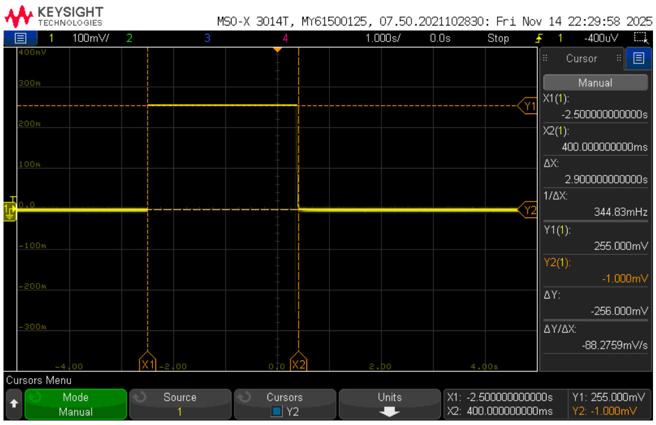

Fig. 11. Scope output

Looking at the rather small percent error given by the comparison between both the simulation and the theoretical, we can assume that this small deviation would come from our resistor and capacitor values, specifically the resistor combination used to get as close to 27k as possible.

B. Astable output (60% duty cycle)

	Theoretical	*Simulated*	*Experimental*
Period [s]	*2*	*2*	*2.055*
Duty Cycle [%]	*60%*	*60.3%*	*58.77%*

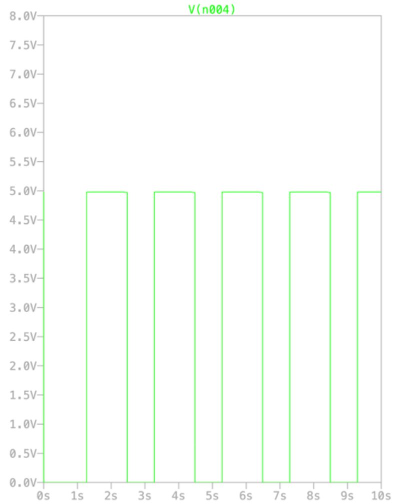

Fig. 12. Simulation Graph

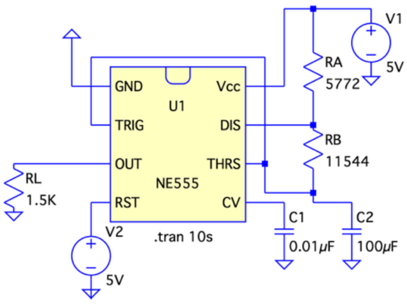

Fig. 13. Simulated circuit

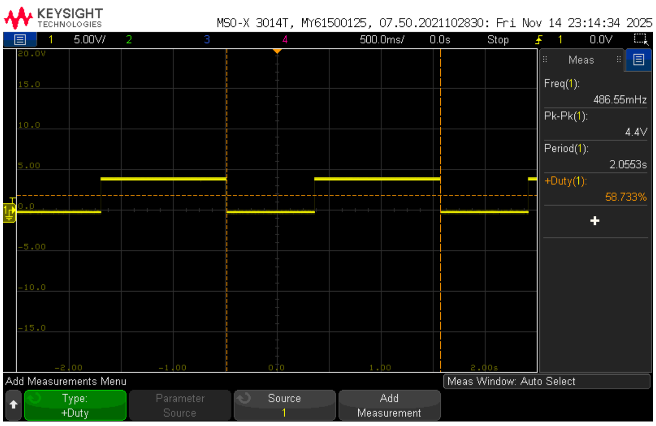

Fig. 14. Scope output

One main reason comes to mind when explaining the small deviation between simulated and experimental values, and that would be the resistor combination of the circuit. More specifically, the value of in the circuit is not anywhere close to any standard resistor value, which results in the need to combine two resistors, each with its own tolerance, and still not encompassing the whole resistor value.

C. *Astable output (75% Duty Cycle)*

	Theoretical	*Simulated*	*Experimental*
Period [s]	*1*	*1*	*.966*
Duty Cycle [%]	*75%*	*75.1%*	*75.15%*

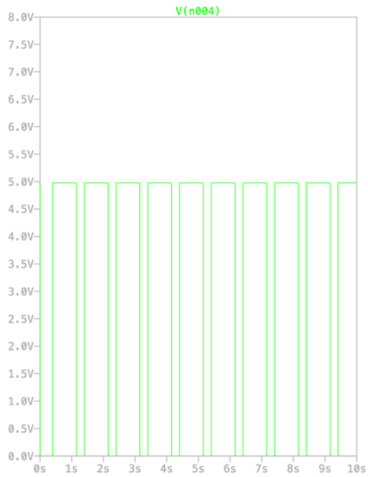

Fig. 15. Simulation Graph

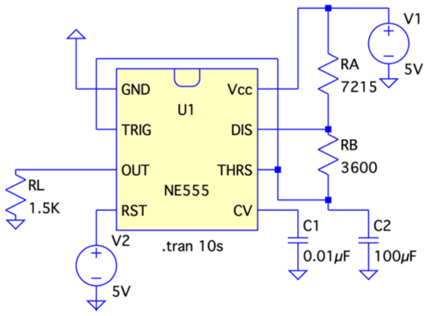

Fig. 16. Simulated circuit

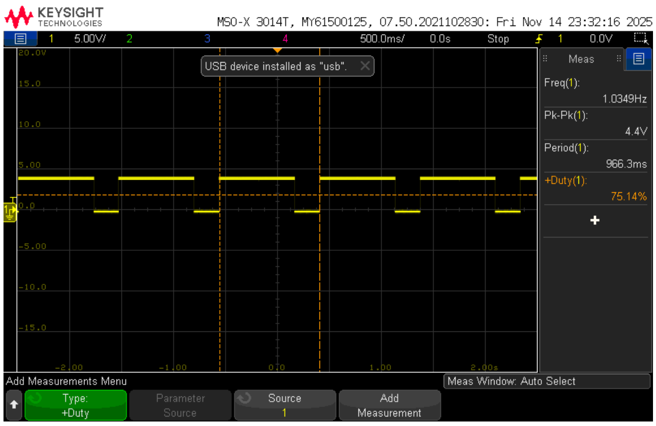

Fig. 17. Scope output

D. Application of the 555 timer

	Theoretical	Simulated	Experimental
Flashing cycle [ms]	220	220	248

PERCENT ERROR: 11.29%

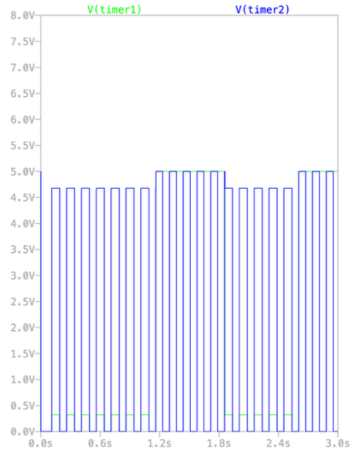

Fig. 18. Simulated Graph

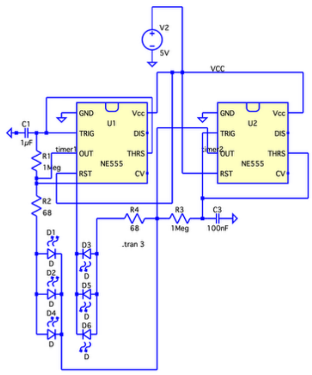

Fig. 19. Simulated Circuit

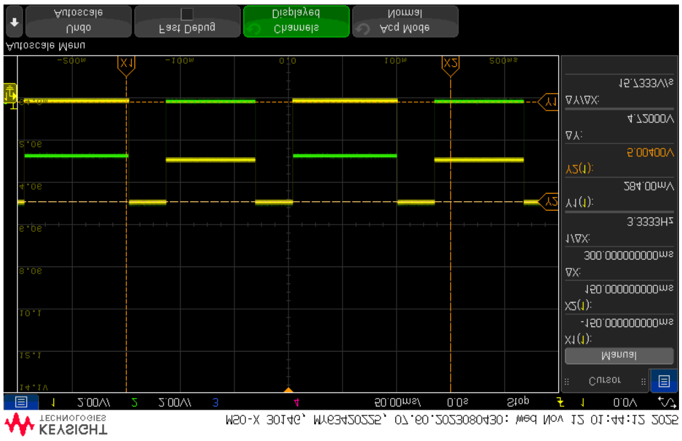

Fig. 20. Scope output

Looking at the discrepancy in the findings, one reason to explain the percent error would be from the tolerance of the capacitors and the resistors, as well as internal tolerances inside the 555 timer itself.

V. Conclusion

Across the experiments, the 555 timer performance was consistent with the theoretical and simulated results. The monostable and astable circuits were able to perform almost perfectly, and the application was able to output flashing LED lights successfully.

Small deviations were observed, and these can be explained by the component tolerances. Specifically, a source for potential deviation would be the use of non-standard resistor values, which in practice would mean combining two or more standard resistors to achieve a value close enough to the theoretical resistance. Additionally, internal tolerances within the 555 IC can help to explain these deviations.

To improve this application, the use of a MOSFET-based 555 timer would be beneficial. The implementation of MOSFETS into the design allows the 555 to have tighter internal tolerances, which would remove one element of the deviation. Additionally, choosing an RC combination as close as possible to standard values or one that is a standard value would help remove deviations from the resistors or capacitors.

References

[1] Texas Instruments, *LM555 Timer*. SNAS548D, rev. D, Jun. 2017. [Online]. Available: https://www.ti.com/lit/ds/symlink/lm555.pdf