

555 TIMER CIRCUIT LOGBOOK

Designing, simulating, building and testing an
astable 555 timer circuit.

ACDA4018

Fundamentals of Electrical and Electronic Systems

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This logbook details the procedure followed, and results obtained from the design, simulation and physical build of an integrated astable 555 timer circuit.

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555 Timer Introduction

The 555 Timer integrated circuit was first invented in the early 1970s and remains today one of the most versatile chips available on the market. Their flexibility of use, coupled with their low manufacturing cost, sees 555 timers used in thousands of different widely available electronic products, and there are estimates which suggest over one billion 555 timers are produced every single year [1].

Applications of 555 Timers are included, but not limited to, precision timing, pulse generation, sequencing, time delay, and modulation of pulses [2].

The Circuit

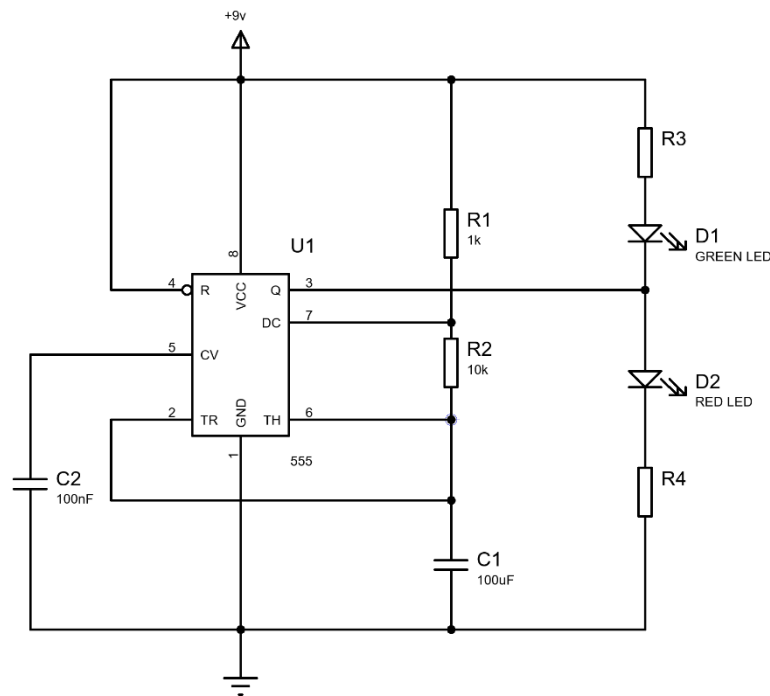


Figure 1: Circuit diagram for the 555 Timer Circuit

In the circuit designed, built and tested in this instance, the 555 Timer acts as an oscillator, generating a square wave which can be viewed as an on-off state. Circuits such as this are referred to as 'astable'. Connecting the circuit up to two LEDs means that the two states are demonstrated by the turning on and off of each LED. The circuit, shown in figure 1, and taken from the in-class brief, shows the 555 timer connected up to a 9V power supply, as well as a series of resistors, capacitors, and two LEDs, one of which is green and the other of which is red.

In this instance, each LED represents the high or low state of the 555 timer. The time for which each LED is on is governed by the two resistors (R_1 and R_2) connected to the chip, as well as the capacitor which is connected to the chip (C_1).

Using the values given, the times for each state (high and low), period, and frequency can be calculated using equations 1-4 below [3] relating to an astable 555 timer circuit:

$$t_{high} = \ln 2 \times (R_1 + R_2) \times C_1 \quad (1)$$

$$t_{low} = \ln 2 \times (R_2) \times C_1 \quad (2)$$

$$T = t_{high} + t_{low} \quad (3)$$

$$f = \frac{1}{T} \quad (4)$$

As can be deduced from the equations, given that the high state time relies on the total of both resistors, and the low state time relies on just one resistor, the high state time period should always be longer than the low state time, which should be demonstrated in the circuit design and build by one light being on for slightly longer than the other.

Theoretical Calculations

With the numbers provided in the brief, and using the formulae 1 to 4 provided in the previous section, the theoretical values for t_{high} , t_{low} , T and f can all be worked out, to compare with the values obtained later on in Proteus when the circuit is designed and simulated.

$$t_{high} = \ln 2 \times (1000 + 10000) \times (100 \times 10^{-6}) = 0.76246s \quad (1)$$

$$t_{low} = \ln 2 \times (10000) \times (100 \times 10^{-6}) = 0.69315s \quad (2)$$

$$T = 0.76246s + 0.69315s = 1.45561s \quad (3)$$

$$f = \frac{1}{1.45561} = 0.68699Hz \text{ or } 0.69Hz \text{ to } 2dp \quad (4)$$

Proteus Simulation

Taking the information, and the circuit diagram provided in the brief, using a 9V input supply and keeping the values of R1, R2, C1 and C2 the same as those provided, the circuit was designed electronically using Proteus software.

R3 and R4 had no value in the brief. The value of the resistors R3 and R4 had to be calculated so as to protect the LEDs from the full 9V supply, a value which far exceeds the breakdown voltage of an LED, and thus would destroy the filament inside the components.

The calculated value of R3 and R4 (both of which could be the same value) was found using the premise of Ohm's Law. Given that a current of between 20 and 25mA was given as the value to trigger the LEDs, with a 9V supply, equation 5 was used to give an ideal resistance value of 450Ω. The proteus circuit used a resistance of 350Ω as there is no widely commercially available 450Ω resistor.

$$V = IR \quad (5)$$

Figure two shows a snapshot of the designed circuit in operation, with the green LED on. In this simulation, the high and low states are represented by the green and red LED switching on and off, representing the oscillation of the square wave produced in the circuit. The wave produced, and the wave representing the change in voltage across the capacitor over time, are displayed in figure three.

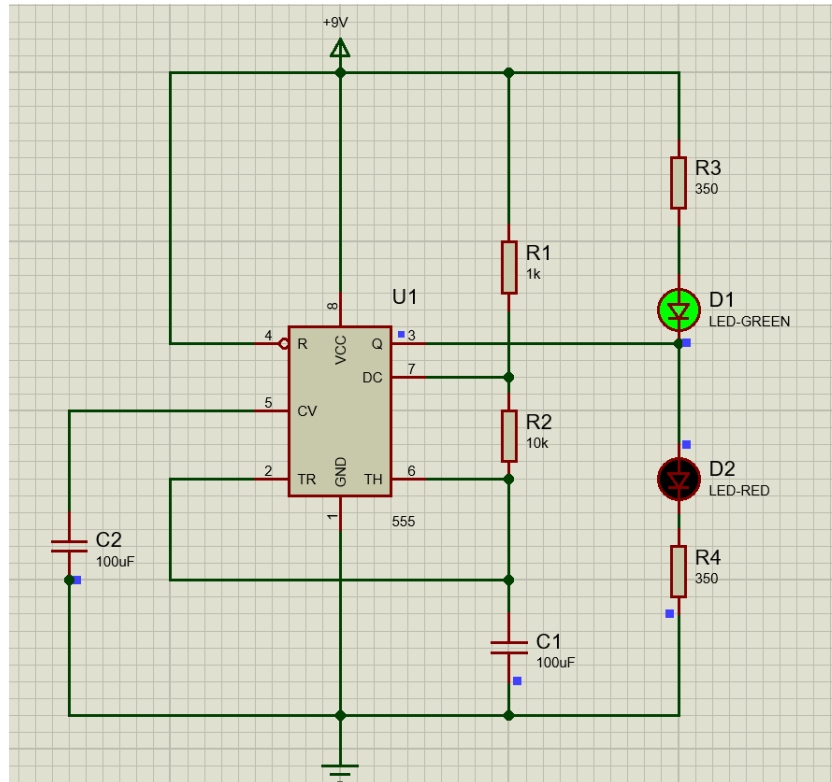


Figure 2: Working Proteus schematic showing a point in time where the green LED is on.

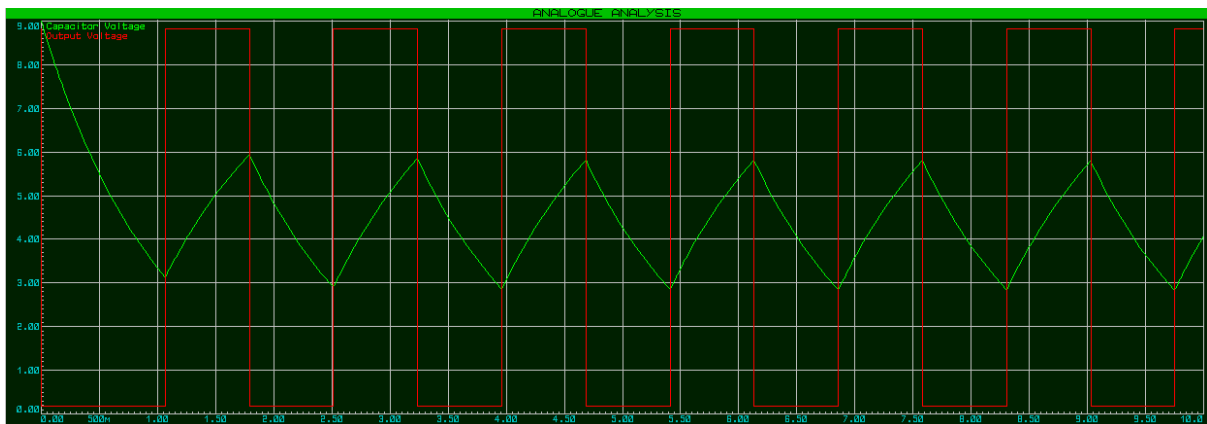


Figure 3: Graph computed by Proteus program over a time of 10 seconds, showing the distinctive square wave of the output voltage representing the on and off state of the 555 timer, and the triangular wave representing the voltage across the capacitor in the circuit.

On figure three, which places both waves on the same graph, the distinctive square waveform can be clearly seen moving between a discrete high and low value almost instantaneously, whilst the green wave representing the voltage across the capacitor is far more gradual, representing the fact that the capacitor is charging and discharging as the simulation goes on.

Table one shows the raw data taken from the graph. The values relate to a single period within the total simulation time, identifying the exact point at which the state of the 555 timer switches on, and then off, within one full wavelength. The 'time in state' column represents the time between the beginning and the end of the particular state, calculated by subtracting the beginning point from the end point.

Time Interval	Beginning Time (s)	End Time (s)	Time in state (s)
t_{high}	1.067	1.791	0.724
t_{low}	1.791	2.514	0.723

Table 1: Table summarising the raw data collected from a single period of the simulation, including calculated values for $T(high)$ and $T(low)$

Using equations 3 and 4, using the values calculated for t_{high} and t_{low} , the values for period, T , and frequency, f , were then calculated.

$$\begin{aligned}
 t_{high} &= 0.724s, t_{low} = 0.723s \\
 T &= 0.724s + 0.723s = 1.447 \text{ (3)} \\
 f &= \frac{1}{1.447} = 0.691Hz \text{ or } 0.69Hz \text{ to } 2dp \text{ (4)}
 \end{aligned}$$

There are small differences in the values of t_{high} and t_{low} from those calculated theoretically, however the trend is overall similar, and the values for T and f are very close to those calculated theoretically. Due to time constraints it was not possible to take the time to identify exactly what was driving the small differences within the values compared to the theoretical ones, but it would be a recommendation for any future undertaking of this task.

Breadboard Circuit

The final task required the production of a physical circuit on a breadboard, a circuit board used for making temporary circuits, where soldering is not required and instead components and wires are inserted into some of the many small holes available on the board.

Notes

Some things that were noted beforehand were:

- Breadboard holes are connected down a line towards the central gap. Across the gap is a different connection.
- At each side of the breadboard are the power rails. Connections to the 9V power supply and to the ground are made here.
- On the breadboard build, 470Ω resistors were used instead of 350Ω resistors used in the Proteus circuit design, as it was desirable to further restrict the current in to the LEDs slightly, as opposed to increasing it notably and risking the diode components being shorted.

Equipment

- Power supply
- Connectors x2
- Breadboard planning sheet (to draw design on)
- Breadboard solderless circuit board
- 555 timer integrated circuit
- LED x2 (green x1, red x1)
- Resistor x4 (10kΩ x1, 1kΩ x1, 470Ω x2)
- Capacitor x2 (100μF x1, 100nF x1)
- Insulated wire of different lengths x16
- Pliers

Construction

- Firstly, a schematic was drawn up on a paper replica of a breadboard to avoid problems in the construction phase. Figure four shows a picture of the labelled schematic plan with key.

-
- Key
- Blue = 10
 - Red = 11
 - Green = 12
 - Yellow = 13
- 10-11-12-13

Figure 4: Schematic drawing plan for construction of the breadboard circuit, with fully labelled key explaining the different colours and annotations.

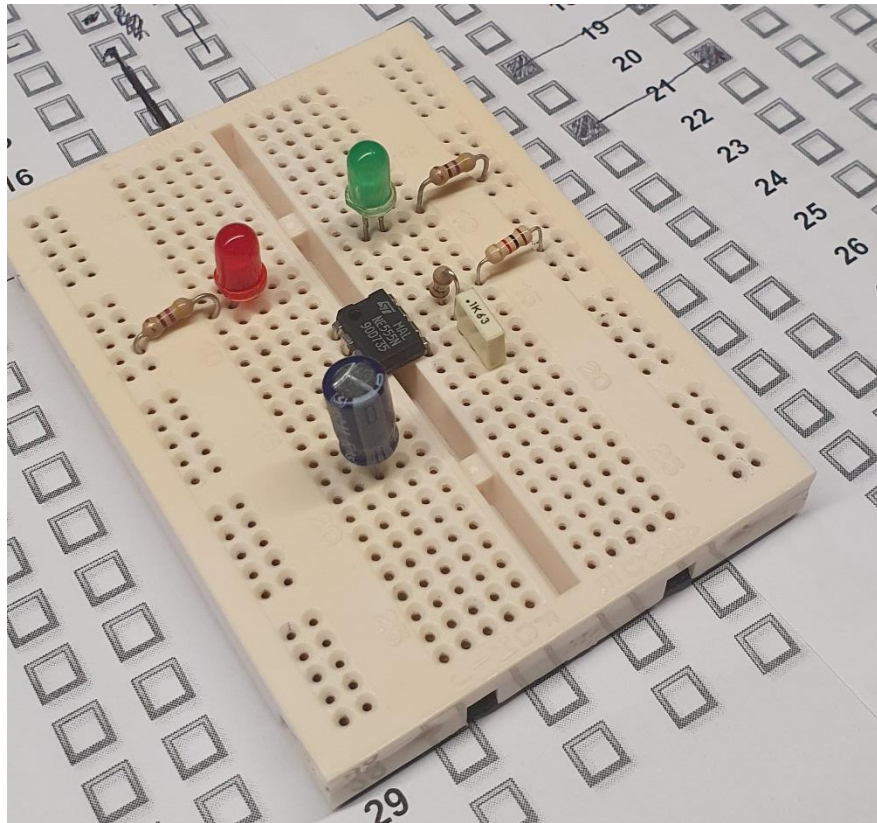


Figure 5: Circuit breadboard with all components added according to the schematic plan.

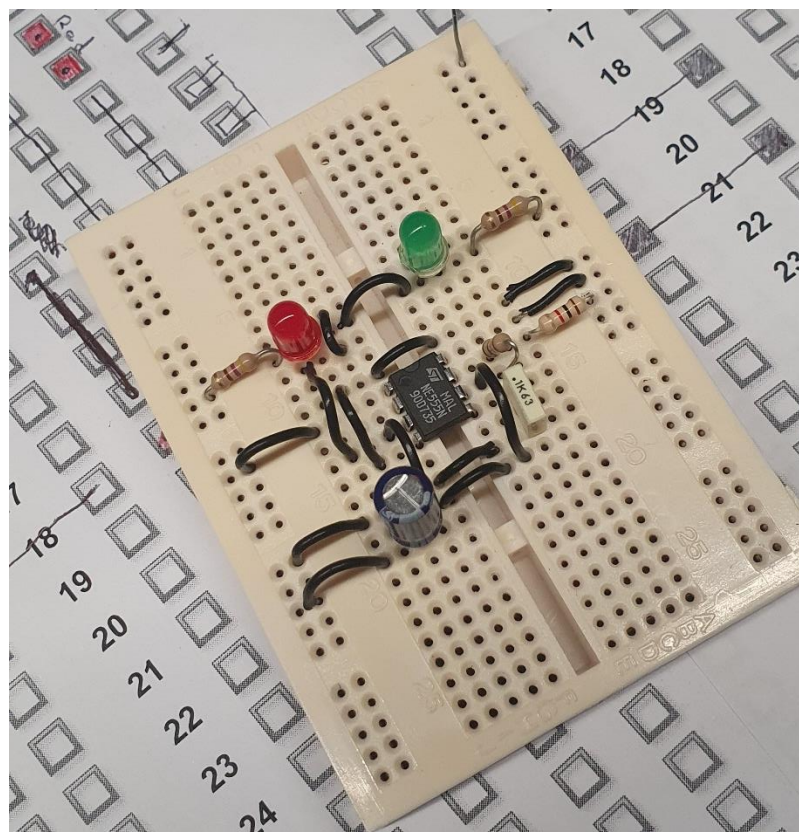


Figure 6: Completed, and untested, breadboard circuit including components and the wires connecting them – just requiring connection to the ground and to the external power supply.

- The circuit was then connected to the external power supply and tested.

Observations

Figure seven shows the first tests carried out on the circuit, which showed both lights on simultaneously. Several attempts to edit the construction of the circuit did not fix the issue. The next decision taken was to change some of the components in the circuit to try to fix the problem, but still every test produced the same result in which both lights were on. Discussions were had with other members of the cohort, all of whom has produced similar looking circuits that worked, so the final change made was to move the entire circuit down the breadboard to see if the issue was the breadboard itself, and this final test proved to be the move that fixed the circuit.

Figures eight and nine show a working circuit, one showing the green LED switched on, and one showing the red LED switched on, representing t_{high} and t_{low} as discussed throughout the report. The difference in current that can be seen on the power supply in each figure is indicative of the changing output voltage. It can be seen that a number of components have been moved between the photos for figure seven and figures eight and nine to accommodate the unresponsive areas of the board.

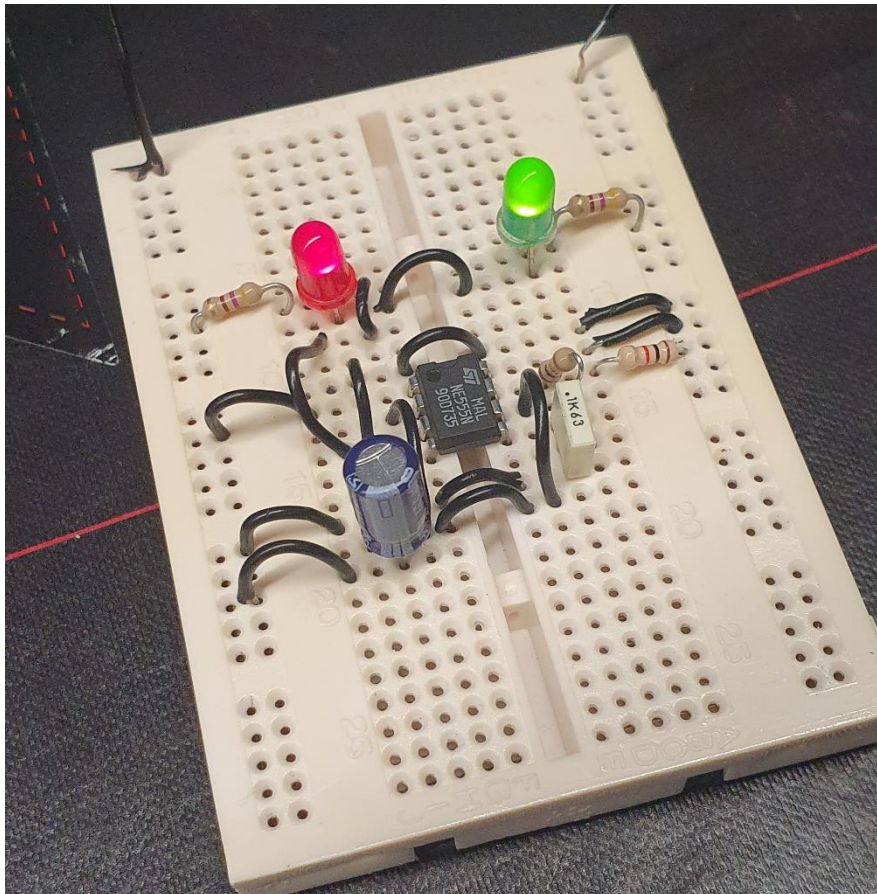


Figure 7: Photo of the first test of the breadboard circuit, showing both LEDs simultaneously on, which is how they remained throughout the test.

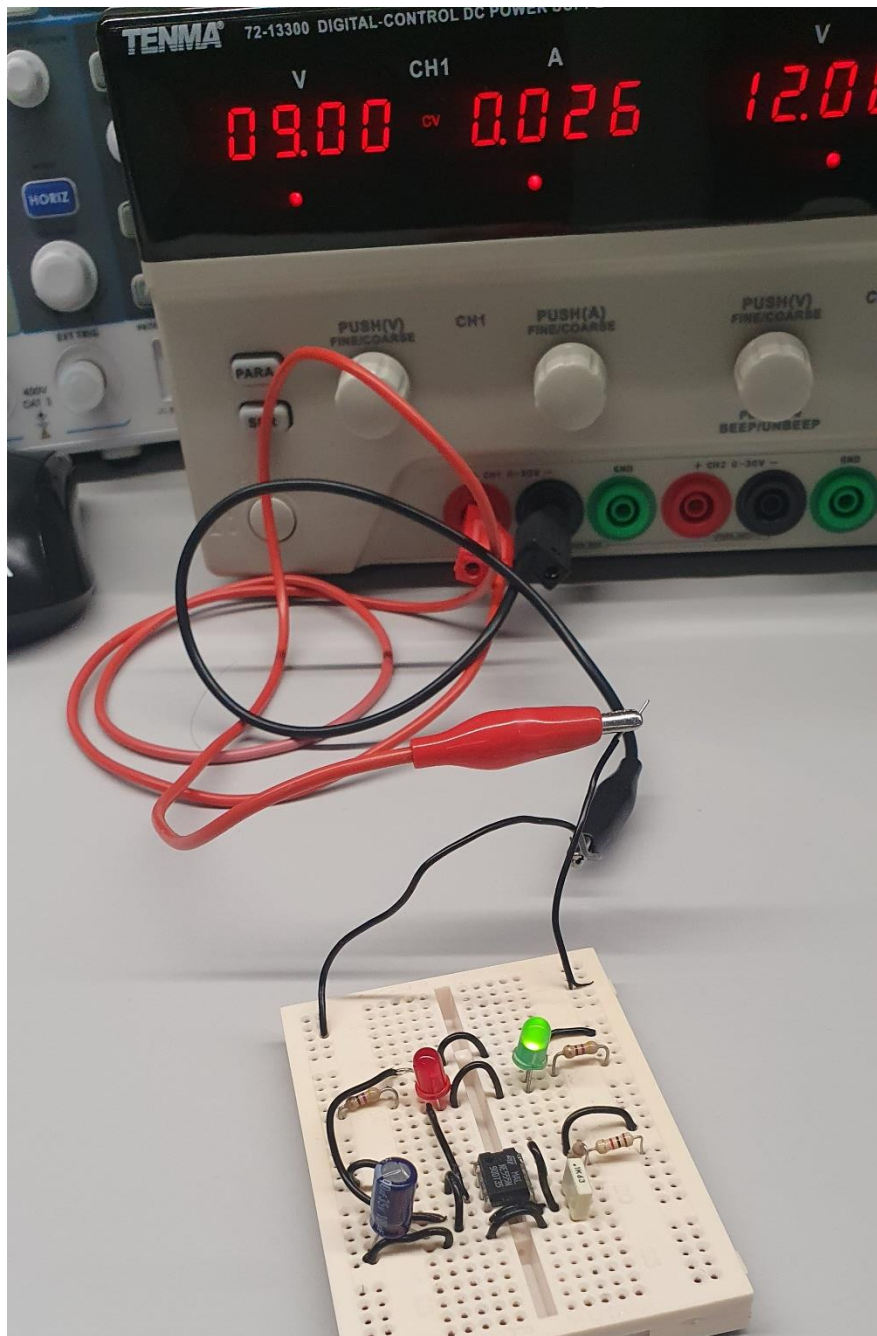


Figure 8: Working breadboard circuit showing a point in time where the green LED is on.

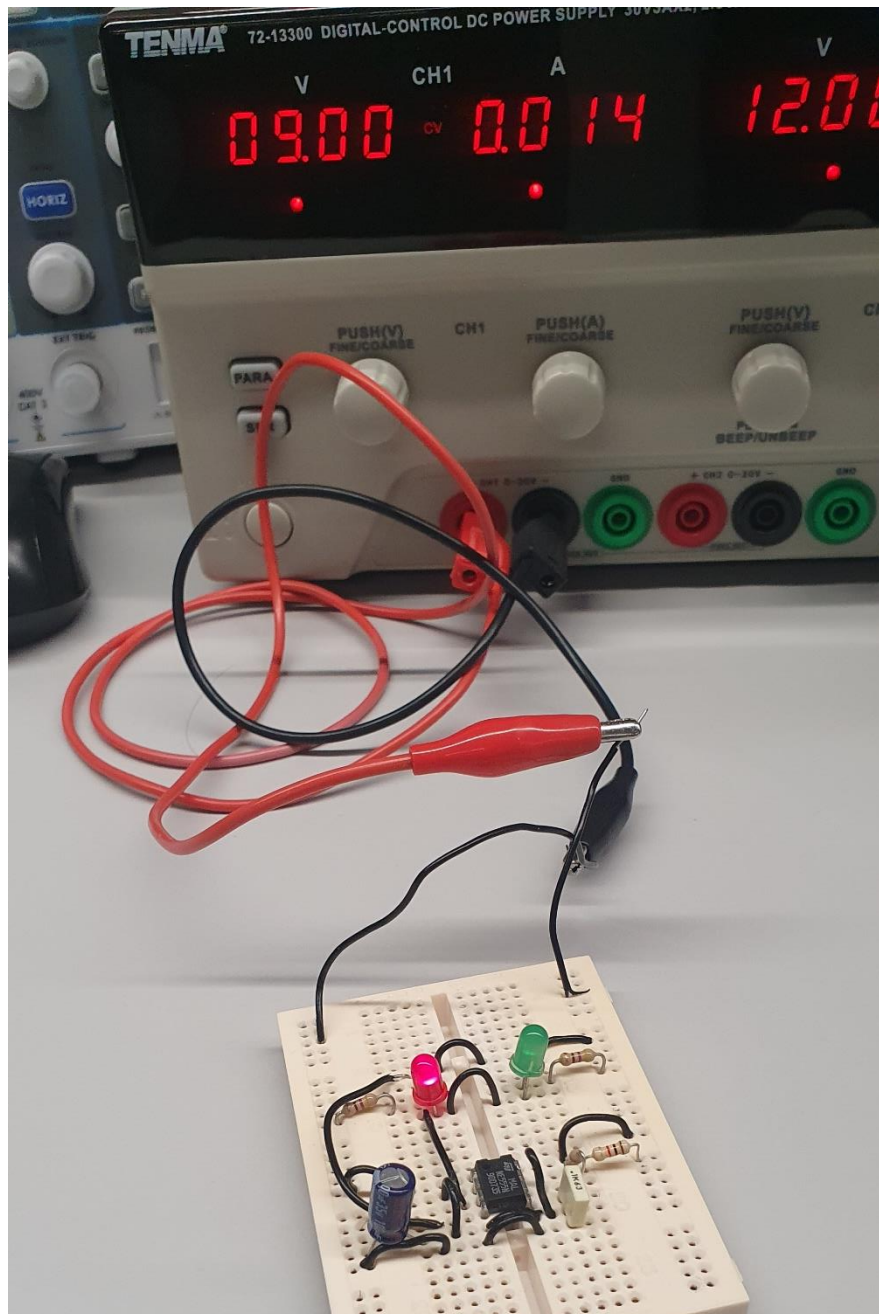


Figure 9: Working breadboard circuit showing a point in time where the red LED is on.

Time constraints prevented calculations from being done on the practical breadboard circuit.

Conclusions

Taking the theory learned from in-class work and literary research, a successful attempt to design, simulate and build an astable 555 timer circuit using the chip as an oscillator to produce intermittent lighting of two LEDs was completed. The results obtained from simulations carried out in Proteus aligned in trend, albeit with slight differences in the values for t_{high} and t_{low} . The knowledge gained from designing the circuit electronically allowed for a successful build of the practical circuit using a breadboard, in which the circuit was captured (after many tests and edits due to a faulty breadboard) appearing to perform in the desired manner, but without calculations to prove mathematically that the circuit was obeying the expected performance of the circuit.

With the opportunity to repeat the experiment, calculations and graphs obtained from the breadboard circuit would be a desirable addition to the process. As well as this, accuracy and understanding of the experiment would be further bolstered with the opportunity to understand why there were small differences between theoretical and Proteus calculations, despite the trends agreeing.

References

- [1] D. Lowe, Electronics All-in-One, Hoboken, NJ: John Wiley & Sons, 2017.
- [2] P. Marian, "IC 555 Timer Datasheet," Electro Schematics, [Online]. Available: <https://www.electroschematics.com/lm555-datasheet/>. [Accessed 12 12 2022].
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