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Circuit Design

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Fundamentals of Electrical and Electronic Systems

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Abstract

This is report on circuit design to demonstrate understanding of the fundamentals of electrical and electronic systems, specifically with regards to component behaviour within a simple 555 timer circuit. It describes the 555 timer circuit, including all components and calculations used to understand aspects of the circuit including unknown resistances, on time and off time, time period and frequency.

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1 Introduction

1.1 Aim

The aim of this report is to demonstrate an understanding of the fundamentals of electronics and electrical systems. This will be done by creating a circuit using the proteus software, simulating that circuit and taking readings. A breadboard will also be used to demonstrate an understanding of the circuit's construction and operation in the real world.

1.2 Scope

This report aims to analyse and describe the components within a 555 timer circuit, including the resistors, the capacitors and the internal components of the 555 timer itself.

Calculations will be used to understand values of two of the resistors of which the values have not been provided, as well as the on time, off time, period and frequency of the circuit.

Tables and graphs will also be used to describe the measurements.

2 Astable 555 timer circuit

For this report it was required that a working astable 555 timer circuit was constructed on both simulation software and in the real world using a breadboard. The 555 timer circuit consisted of a series of capacitors, resistors, LEDs, a power supply and a 555 timer chip. The resistors prevented too much current from running into the 555 timer and overloading the internal transistors, causing shorts or breaking the chip. The capacitors allowed voltage regulation across the 555 timer and their capacitance ultimately dictated the timing of the on time and off time of the circuit. The LEDs gave a visual signal that the circuit was working correctly, where the red and green LEDs alternated between which was lit in order to visually demonstrate the on time and off time. The 555 timer itself is a complex logic chip which consists of three 5kOhm resistors and a series of transistors, routing power through various segments in a sequence of events to alternate power supply to different components, as can be seen in figure 1 below

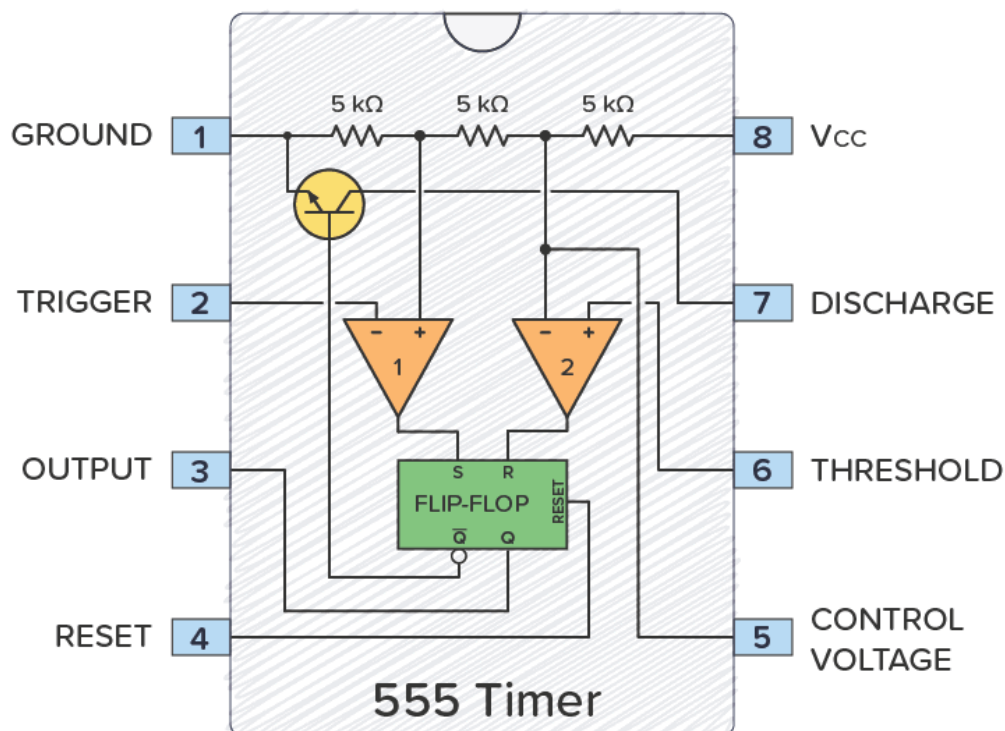


Figure 1 - 555 Timer Block Diagram[1]

The 8 pins provide the following functions and controls[1]:

1. Ground – this connects to the ground or negative side of a battery to close the circuit
2. Trigger – when the power supply to this pin falls to less than one-third of the voltage input, the output of the 555 timer supplies 7.5v to the components (this is 9v supply -1.5v saturation)
3. Output – This pin provide a voltage output from the 555 timer
4. Reset – This pin resets the transistor state of the 555 timer when voltage supply drops, indicating that voltage supply to this pin is normally high.
5. Control voltage – this pin controls the threshold voltage of the threshold pin, and can be used in conjunction with R1, R2 and C1 to adjust the frequency of the circuit.
6. Threshold – This pin sets drops the output once it has risen above two thirds of the input voltage.
7. Discharge – This pin connects to the ground to provide a low output voltage, diverting voltage in order to reduce the output voltage through the output pin.
8. VCC supply – This pin is the positive power supply for the 555 timer.

The block diagram shown in Figure 1 also describes the internal components of the 555 timer which can be described in the following table:

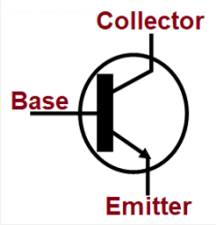
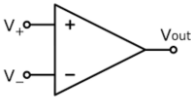
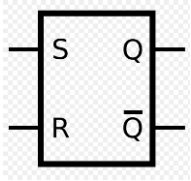
Symbol	Name	Description
	NPN Discharge Transistor	The NPN discharge transistor is used to discharge any externally connected capacitor, ensuring circuit functionality
	Comparator	Comparators are devices which compare two analog input voltages at a positive and negative input terminal(also known as non-inverting and inverting). If the voltage at the positive terminal is higher than the voltage at the negative terminal, the output of the comparator will be high. If it is inverse, the output will be low.
	Resistor	Within the 555 timer, there are three 5kΩ Resistors connected in series between the supply voltage and ground. These are what gives the name to the timer.
	Set-Reset Flip Flop	The SR flip flop takes inputs from the outputs of the comparators to determine output at either Q or $\bar{Q}$.

Table 1 - 555 Timer Block Diagram Description[2]

The 555 timer can be used in three modes:

- Astable
- Monostable
- Bistable

Astable

Astable means that the output will never be stable and the output will continually switch between high and low, working as an oscillator. This can be seen by the circuit as it switches between illuminating the red and green LEDs.

Monostable

Monostable means the out is stable in only one state and will always return to this state even when pushed out of stability.

Bistable

Bistable means the output is stable in both states, however will remain in either state until it is pushed to the other state. it does this using the trigger and threshold pins.[1]

2.1 Schematic of Circuit in Proteus

Below can be seen the schematic of the 555 timer circuit as drawn in proteus. This was simulated and probed at points to test the period, frequency and voltage drop. Whilst the graph is represented in figure 2, a more detailed representation of this can be seen later in the report.

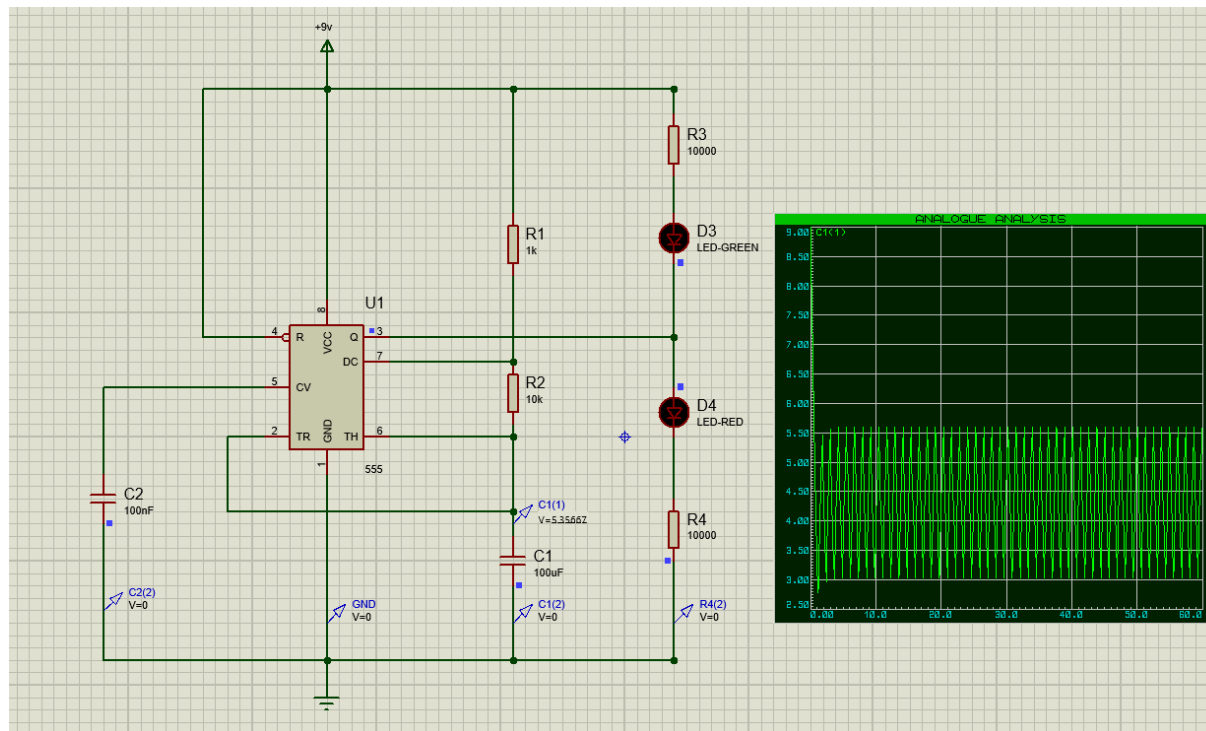


Figure 2 - Simulation Schematic and Voltage Discharge in Proteus

2.2 Calculation of Resistor values for R3 and R4

Although during the simulated and practical circuits 10kOhm resistors were used, it is important to calculate the resistance of what resistors would have used with respect to the other components.

In order to calculate the resistance, the following formulae will be used:

$$T = T_{on} + T_{off} = 0.693(R_3 + 2R_4) \times C_1$$

Equation 1- Relationship Between Time Period, Resistance and Capacitance in a 555 Timer[3]

Where:

T = Time period

T_{on} = On time

T_{off} = Off time

0.693 = exponential of $\ln(2)$

R_3 and R_4 = Resistors 3 and 4

C_1 = Capacitor 1

Choosing a time period of 1s, this formula can be re-arrange to make R_3 and R_4 the subject:

$$R_3 + 2R_4 = \frac{1}{0.693 \times C_1}$$

Plug in the figures which are known

$$R_3 + 2R_4 = \frac{1}{0.693 \times (100 \times 10^{-6})} = 14430\Omega$$

All that is left is to identify two resistor values from the table of standard resistor values seen in Annex 1 [4] to get as close to this result as possible.

If R_3 is selected at 9.1k Ω , then R_4 can be calculated:

$$9100 + 2R_4 = 14430$$

$$2R_4 = 5330$$

$$R_4 = 5330$$

$$R_4 = 2665$$

Using this number and the table of standard resistor values, a 2.7kΩ resistor can be selected to make this work.

Therefore the resistance values if the time period is 1s can be calculated as:

$$R_3 = 9.1k\Omega$$

$$R_4 = 2.7k\Omega$$

In the event that the total resistance were to be raised or lowered, it would affect the time period and overall the on time and off time of the circuit.

2.3 Calculation of On time and Off time

Using the prior figures for R_3 and R_4 , the following formulae can be used to calculate on time and off time:

On time

$$T_{on} = 0.693(R_3 + R_4) \times C_1 = 0.693(9100 + 2700) \times (100 \times 10^{-6}) = 0.81774s$$

Equation 2 - On Time Formula[3]

Off time

$$T_{off} = 0.693R_4 \times C_1 = 0.693 \times 2700 \times (100 \times 10^{-6}) = 0.18711s$$

Equation 3 - Off Time Formula[3]

Therefore

$$T_{on} = 0.82s \text{ to 2 d.p.}$$

$$T_{off} = 0.18s \text{ to 2 d.p.}$$

2.4 Calculation of Period

Feeding this back into this original formula, we can check the time period matches up with what we chose:

$$T = T_{on} + T_{off} = 0.82 + 0.18 = 1s$$

2.5 Calculation of Frequency

Frequency is a measurement of how many times in one second that the cycle repeats itself, and can be calculated using the following formula:

$$f = \frac{1}{T}$$

Equation 4 - Frequency Formula[3]

Where:

f = frequency(Hz)

T = Time period(s)

Plug in our numbers:

$$f = \frac{1}{1} = 1Hz$$

2.6 Table of Timing Measurements

The table of timing measurements for the capacitor discharge, taken from the actual simulation can be seen below:

TIME(s)	C1(V)	TIME(s)	C1(V)	TIME(S)	C1(V)
0	8.99991	10.04285	4.06062	21.02083	3.31672
0.987979	3.35608	11.07263	3.03679	21.99917	3.72239
2.00289	4.44778	12.10386	3.72238	23.03043	4.56496
3.032673	5.5611	12.98087	5.31896	24.06021	5.60525
4.063944	4.88888	13.95926	4.90519	25.09148	4.90519
4.992363	3.56967	14.99051	4.06067	26.0199	3.57629
5.919294	3.71965	16.02029	3.03681	26.94683	3.72239
6.950545	4.56393	17.05152	3.72239	27.97808	4.56496
8.007504	5.45587	17.97994	5.05472	29.00786	5.60525
8.033212	5.3186	18.90691	4.90519	30.03914	4.90519
9.0116	4.90505	19.93816	4.06067		

Table 2 - Capacitor C1 Discharge Values(Proteus)

The actual data recorded was far more detailed, however for the purpose of the report the data points were reduced to the nearest second and only the first 30 seconds were used for the range.

2.7 Capacitor Voltage Graph

To ensure the graph described in figure 2 was accurately shown, the figures were exported to excel and a graph generated as a result. This can be seen below.

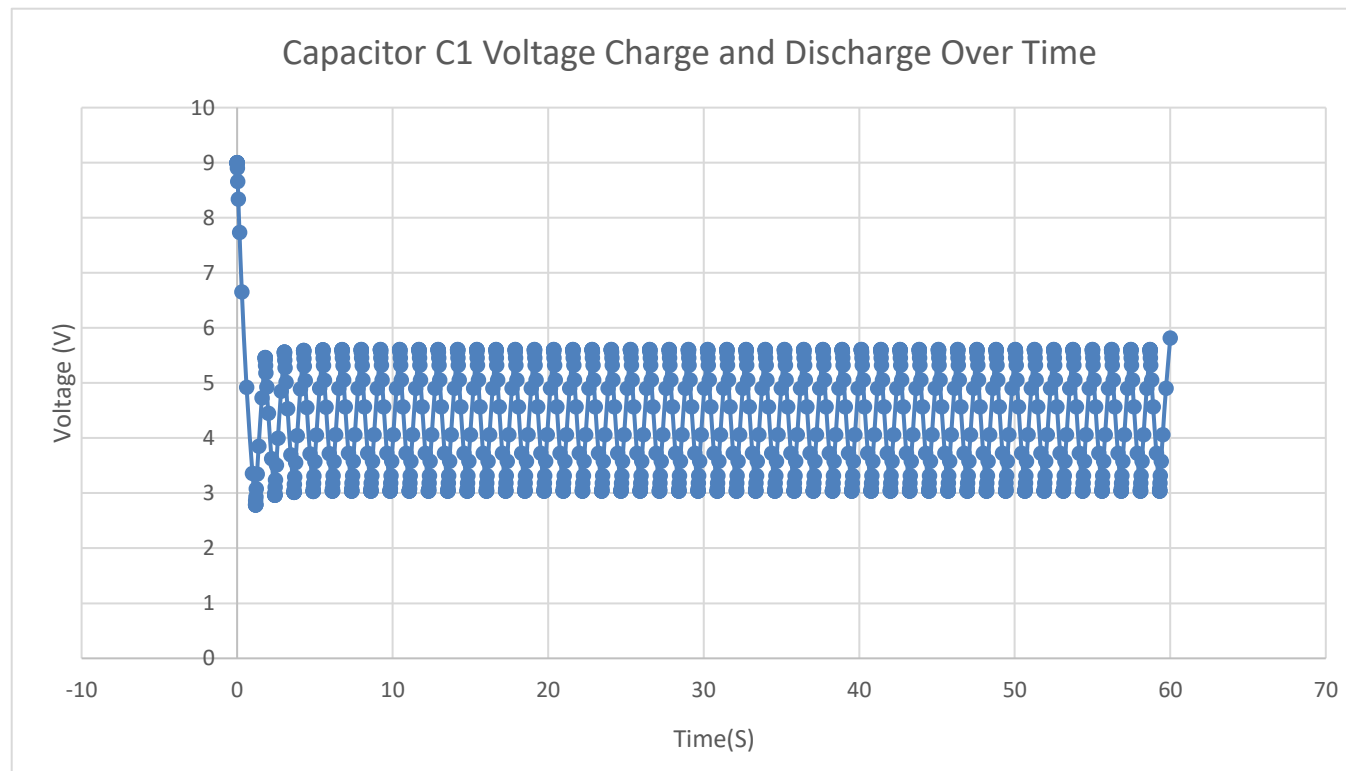


Figure 3 – Capacitor C1 Voltage Discharge Graph(Proteus)

3 555 Timer Breadboard Build

3.1 Construction and Testing

For the construction and testing of the breadboard build, it was first simulated in online breadboard modelling software Tinkercad[4], as shown in figure 4 below

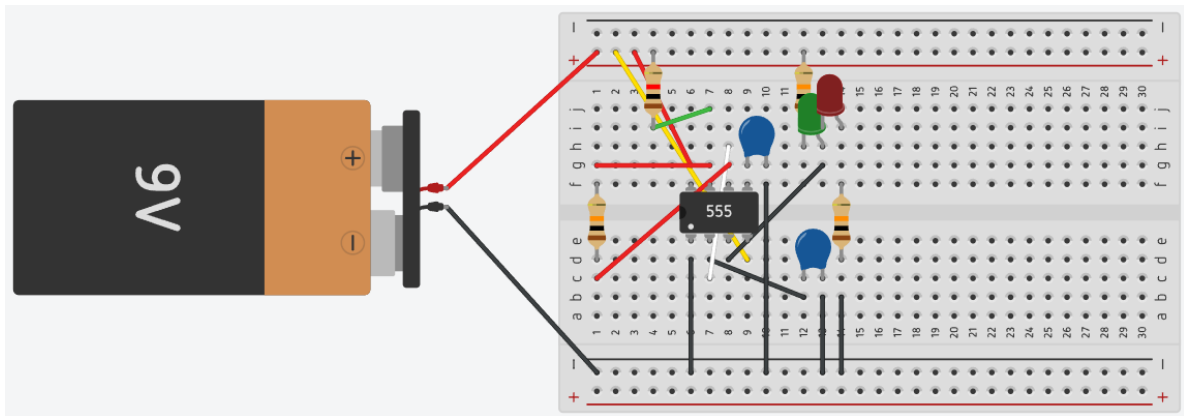


Figure 4 - Breadboard Schematic[5]

This was then used to build the breadboard circuit, with the only differences being that the resistors were able to shorten the connection lengths, as the software lacked the ability to allow resistors to connect diagonally. This is shown below in figure 5

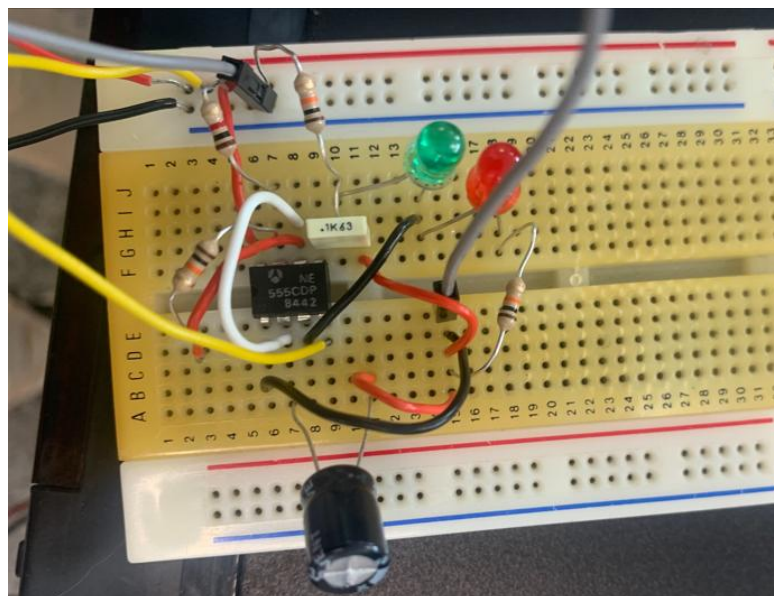


Figure 5 - Breadboard Build

3.2 Timing Measurements

For the breadboard model, timings were taken manually by counting the on-off times of one of the LEDs. It wasn't important which LED was analysed as they alternated equally, however the green LED was analysed over a 30 second period.

LED	No. of times LED lit up in 30 seconds
Green	19

Table 3 - LED Analysis

As can be seen in table 3, the green LED lit for a total of 19 times in 30 seconds.

This allows us to calculate the on time-off time, the period and the frequency of the circuit.

3.2.1 On Time-Off Time

The on time-off time can be calculated by dividing the seconds by the number of times it lit up, then dividing that number by two, as it would have been off for half the time due to equal resistor values used.

$$\frac{30s}{19} = 1.579s$$

$$\frac{1.579}{2} = 0.789s$$

Therefore the on time-off time was approximately 0.789s.

3.2.2 Period

As described before, the period is the amount of time in which it takes the circuit to do one full cycle. This can be seen by the initial equation in the on time-off time calculations, therefore the period is 1.579s

3.2.3 Frequency

The frequency can be calculated using the equation:

$$\frac{1}{T} = f$$

This is used to understand how many times per second the circuit oscillated.

$$\frac{1}{1.579s} = 0.63hz$$

Comparing this to the Frequency given by the calculations undertaken previously to assign resistor values, it can be seen increasing the resistor values also increases the frequency.

3.3 Capacitor Voltage and Output Voltage Graphs

For this part of the report, a multimeter was connected to the breadboard to measure the capacitor voltage discharge at 1 second intervals, the readings can be seen in Annex 2 and have been visually represented in the graph below.

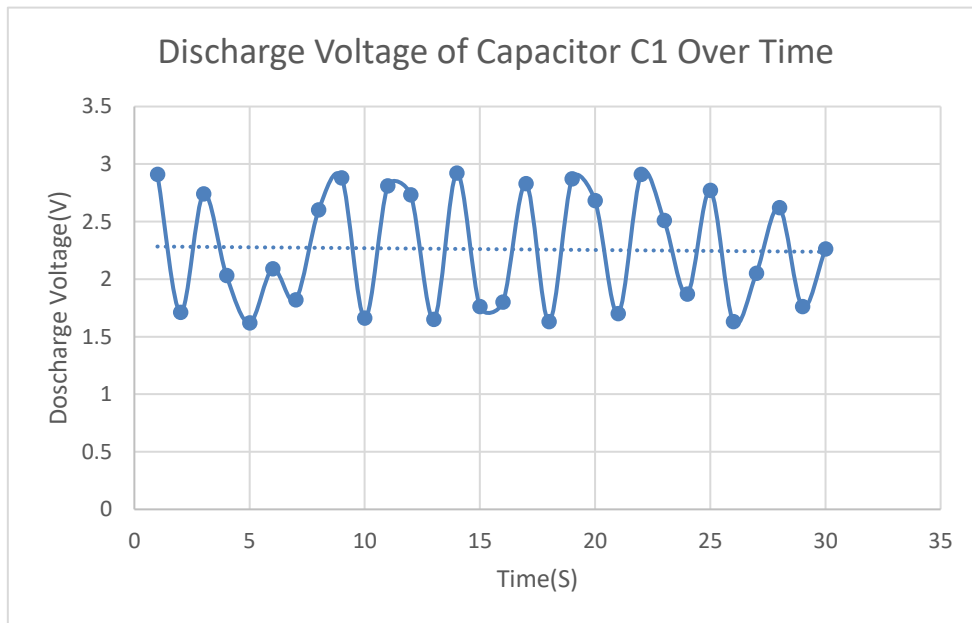


Figure 6 - Capacitor C1 Voltage Discharge Graph (Breadboard)

A trend line has been included in this graph to reflect the stability of the capacitor during its continuous cycling of discharging and charging.

Although the graph is far less consistent than that of the graph produced by the proteus software, this is simply down to human factors and reduction of reference points. In comparison, the proteus graph used 450 reference points in the same time period, compared to 30 reference points taken for this analysis.

Another notable difference is that of the discharge voltage figures, where the proteus simulation provided readings which doubled in magnitude. This was due to the supply voltage for the breadboard being half that of the simulation.

4 References

- [1] Ohmify AS. 2025. 555 Timer Tutorial: How It Works and Useful Example Circuits. Available at: <https://www.build-electronic-circuits.com/555-timer/>. Accessed 20250719.
- [2] Play With Circuit. 2025. 555 Timer IC – Block Diagram, Working, Operating Modes. Available at: <https://playwithcircuit.com/555-timer-ic-working-and-operating-modes/>. Accessed 20250720.
- [3] EE Tech Group, LLC. ND. 555 Timer Astable Oscillator Circuit. Available at: <https://www.allaboutcircuits.com/tools/555-timer-astable-circuit/>. Accessed 20250719.
- [4] The Open University. 2025. 2.4 Colour coding and standard resistor values. Available at: <https://www.open.edu/openlearn/science-maths-technology/an-introduction-electronics/content-section-2.4>. Accessed 20250719.
- [5] Autodesk Inc. 2025. Breadboard Simulator Practice. Available at: <https://www.tinkercad.com/things/kBnlbPHnn8z-breadboard-simulator-practice>. Accessed 20250626.

5 Annexes

5.1 Annex 1 – Table of Standard Resistor Values

1.0	10	100	1.0 k	10 k	100 k	1.0 M
1.1	11	110	1.1 k	11 k	110 k	1.1 M
1.2	12	120	1.2 k	12 k	120 k	1.2 M
1.3	13	130	1.3 k	13 k	130 k	1.3 M
1.5	15	150	1.5 k	15 k	150 k	1.5 M
1.6	16	160	1.6 k	16 k	160 k	1.6 M
1.8	18	180	1.8 k	18 k	180 k	1.8 M
2.0	20	200	2.0 k	20 k	200 k	2.0 M
2.2	22	220	2.2 k	22 k	220 k	2.2 M
2.4	24	240	2.4 k	24 k	240 k	2.4 M
2.7	27	270	2.7 k	27 k	270 k	2.7 M
3.0	30	300	3.0 k	30 k	300 k	3.0 M
3.3	33	330	3.3 k	33 k	330 k	3.3 M
3.6	36	360	3.6 k	36 k	360 k	3.6 M
3.9	39	390	3.9 k	39 k	390 k	3.9 M
4.3	43	430	4.3 k	43 k	430 k	4.3 M
4.7	47	470	4.7 k	47 k	470 k	4.7 M
5.1	51	510	5.1 k	51 k	510 k	5.1 M
5.6	56	560	5.6 k	56 k	560 k	5.6 M
6.2	62	620	6.2 k	62 k	620 k	6.2 M
6.8	68	680	6.8 k	68 k	680 k	6.8 M
7.5	75	750	7.5 k	75 k	750 k	7.5 M
8.2	82	820	8.2 k	82 k	820 k	8.2 M
9.1	91	910	9.1 k	91 k	910 k	9.1 M

Table 4 - Standard Resistor Values[4]

5.2 Annex 2 – Table of Capacitor Discharge Values in One Second Intervals (Breadboard Analysis)

TIME(s)	C1(V)	TIME(s)	C1(V)	TIME(s)	C1(V)
1	2.91	11	2.81	21	1.7
2	1.71	12	2.73	22	2.91
3	2.74	13	1.65	23	2.51
4	2.03	14	2.92	24	1.87
5	1.62	15	1.76	25	2.77
6	2.09	16	1.8	26	1.63
7	1.82	17	2.83	27	2.05
8	2.6	18	1.63	28	2.62
9	2.88	19	2.87	29	1.76
10	1.66	20	2.68	30	2.26

Table 5 - Capacitor C1 Discharge Values(Breadboard)