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Report 5

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Abstract

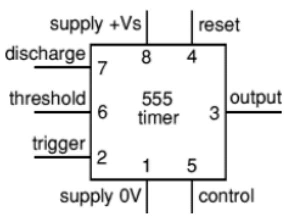
The 555 timer IC is one of the most versatile and widely used integrated circuits in electronics. In this experiment, the 555 timer is configured in astable mode to generate a continuous square wave output. The frequency and duty cycle of the output waveform depend on the external resistors and capacitor connected to the circuit. The experiment investigates the working principle of the astable multivibrator, verifies theoretical frequency expressions, and studies the effect of varying resistance and capacitance values. Observations are recorded using a CRO, and the experimental values are compared with theoretical predictions.

Contents

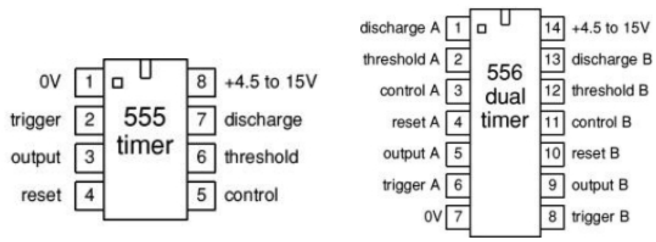
1 Introduction

The 555 timer IC is a highly stable device used for generating precise time delays and oscillations. It operates in three modes: monostable, bistable, and astable. Among these, the astable mode produces a continuous square wave without requiring any external triggering. Due to its simplicity, reliability, and low cost, the 555 timer is widely used in waveform generators, clocks, LED flashers, and pulse modulation circuits.

The 556 timer is a dual version of the 555 timer, consisting of two independent timers within a single package. Both 555 and 556 timers operate within a voltage range of approximately 4.5V to 15V and are capable of sourcing and sinking current.



Example circuit symbol



Actual pin arrangements of 555 and 556 ICs

1.1 Aim

To study the operation of the 555 timer IC in astable mode and to determine the frequency of oscillation for different values of resistance and capacitance.

1.2 Components and Instruments

The following components and instruments are used:

1. Power supply, 1 No : +15 V
2. Resistors: 1 kΩ, 10 kΩ, 100 kΩ, and 1 MΩ
3. Capacitors: 0.001 μF, 0.01 μF, 0.1 μF, 1 μF, and 10 μF
4. IC 555: 1 No
5. LED, 1 Nos
6. Breadboard = 1 No
7. CRO = 1 No
8. Single strand wires = 4–5 Nos.

2 Theory

2.1 Astable Multivibrator

An astable multivibrator is a free-running oscillator that continuously switches between two unstable states without requiring any external triggering signal. It generates a periodic square wave output, making it widely useful in clock generation, pulse generation, and LED flashing circuits.

In the 555 timer configured in astable mode, a capacitor repeatedly charges and discharges through two resistors R_1 and R_2. When the capacitor voltage reaches $\frac{2}{3}V_{CC}$, the internal comparator resets the output to low and the discharge transistor turns on, allowing the capacitor to discharge. When the voltage drops below $\frac{1}{3}V_{CC}$, the output switches to high again, and the cycle repeats.

Thus, the output oscillates continuously between high and low states, producing a square waveform. Since the circuit has no stable state, it continuously oscillates, hence the name "astable".

2.2 Monostable Multivibrator

A monostable multivibrator, also known as a one-shot multivibrator, has one stable state and one quasi-stable (temporary) state. The circuit remains in its stable state indefinitely until it is triggered by an external input signal.

In the 555 timer monostable configuration, the output is initially low. When a trigger pulse is applied (voltage drops below $\frac{1}{3}V_{CC}$), the output switches to a high state and the capacitor begins to charge through a resistor. When the capacitor voltage reaches $\frac{2}{3}V_{CC}$, the output automatically returns to the low state.

Thus, for each trigger input, the circuit produces a single output pulse of fixed duration.

The pulse width (time for which output remains high) is given by:

$$T = 1.1RC$$

Where,

- R is the resistance in ohms (Ω)
- C is the capacitance in farads (F)

After the pulse duration, the circuit returns to its stable state and waits for the next trigger signal. This makes the monostable multivibrator useful in timing applications, pulse generation, and delay circuits.

2.3 Bistable Multivibrator

A bistable multivibrator is a digital circuit that has two stable states and can remain indefinitely in either of these states until an external trigger is applied. Unlike astable and monostable multivibrators, the bistable multivibrator does not change states automatically. Instead, it requires external triggering signals to switch between its two stable states.

In the context of the 555 timer IC, the bistable mode operates similarly to a flip-flop. The output can be set to a high state or reset to a low state using the trigger and reset inputs respectively. When a negative pulse (voltage less than $\frac{1}{3}V_{CC}$) is applied to the trigger input, the output switches to the high state. Conversely, when the reset pin is driven low (below approximately $0.7\,V$), the output is forced to the low state regardless of other inputs.

The bistable configuration does not require any timing capacitor, as there is no charging or discharging cycle involved. The output remains latched in its current state until another triggering event occurs. This makes the bistable multivibrator useful in memory storage, switching circuits, and digital logic applications.

The two stable states of the output can be represented as:

$$Q = 1 \quad \text{(High state)}$$

$$Q = 0 \quad \text{(Low state)}$$

Thus, the 555 timer in bistable mode functions as a simple storage element or flip-flop, where the output state depends entirely on the applied input signals rather than time-dependent components.

2.4 Astable Operation

In astable mode, the capacitor charges through resistors R_1 and R_2 and discharges through R_2. The charging and discharging cycle generates a square wave output.
The total time period is given by:

$$T = 0.7(R_1 + 2R_2)C_1$$

The frequency is:

$$f = \frac{1.4}{(R_1 + 2R_2)C_1}$$

The time period consists of two parts:

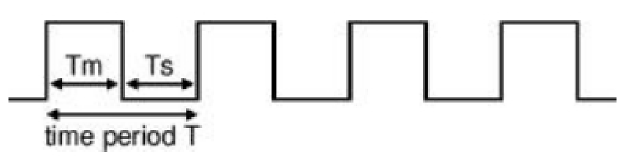
$$T = T_m + T_s$$

Mark time (output HIGH):

$$T_m = 0.7(R_1 + R_2)C_1$$

Space time (output LOW):

$$T_s = 0.7R_2C_1$$



555 astable output, a square wave
(Tm and Ts may be different)

2.5 Inputs of 555/556 Timer for operating in astable mode

Trigger Input: The trigger input activates the timer when the voltage falls below $\frac{1}{3}V_{CC}$. It causes the output to become high.

Threshold Input: The threshold input resets the output when the voltage exceeds $\frac{2}{3}V_{CC}$.

Reset Input: An active-low input that forces the output to low regardless of other inputs.

Control Input: Used to modify the threshold voltage (normally $\frac{2}{3}V_{CC}$). It is usually bypassed with a capacitor to reduce noise.

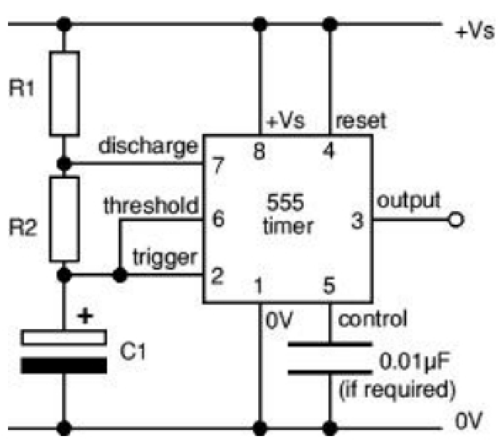
Discharge Pin: Connected internally to a transistor that discharges the capacitor when the output is low.

2.6 Choosing R_1, R_2, and C_1 while operating 555/556 Timer in astable mode

The selection of resistor and capacitor values determines the frequency and duty cycle:

1. Choose C_1 based on the desired frequency range.
2. Select R_2 using:
$$R_2 = \frac{0.7}{fC_1}$$
3. Choose $R_1 \approx \frac{R_2}{10}$ for near equal duty cycle.
4. Ensure resistors are within $1k\Omega$ to $1M\Omega$.

2.7 Circuit Diagram for operating 555 Timer in astable mode



555 astable circuit

3 Observation Table and Discussion

3.1 Observation Table

Sl. No.	C_1	R_1	R_2	f (Theory)	T_m (Expt)	T_s (Expt)	T=$T_m + T_s$ (Expt)	f (Expt)	% error
1	0.001 μF	1 kΩ	10 kΩ	68 kHz	8 μs	7 μs	15 μs	67 kHz	1.47
2	0.001 μF	10 kΩ	100 kΩ	6.8 kHz	80 μs	72 μs	152 μs	6.6 kHz	3.03
3	0.001 μF	100 kΩ	1 MΩ	680 Hz	750 μs	675 μs	1425 μs	702 Hz	3.24
4	0.01 μF	1 kΩ	10 kΩ	6.8 kHz	72 μs	68 μs	140 μs	7.1 kHz	4.41
5	0.01 μF	10 kΩ	100 kΩ	680 Hz	800 μs	720 μs	1520 μs	658 Hz	3.24
6	0.01 μF	100 kΩ	1 MΩ	68 Hz	9.0 ms	7.2 ms	16.2 ms	66 Hz	2.94
7	0.1 μF	1 kΩ	10 kΩ	680 Hz	760 μs	720 μs	1480 μs	676 Hz	0.59
8	0.1 μF	10 kΩ	100 kΩ	68 Hz	8.0 ms	7.6 ms	15.6 ms	64 Hz	5.88
9	0.1 μF	100 kΩ	1 MΩ	6.8 Hz	80 ms	80 ms	160 ms	6.3 Hz	7.35
10	1 μF	1 kΩ	10 kΩ	68 Hz	7.5 ms	6.9 ms	14.4 ms	69 Hz	1.47
11	1 μF	10 kΩ	100 kΩ	6.8 Hz	80 ms	76 ms	156 ms	6.4 Hz	5.88
12	1 μF	100 kΩ	1 MΩ	0.68 Hz	800 ms	760 ms	1560 ms	0.64 Hz	5.88
13	10 μF	1 kΩ	10 kΩ	6.8 Hz	72.5 ms	65.5 ms	138 ms	7.3 Hz	7.35
14	10 μF	10 kΩ	100 kΩ	0.68 Hz	800 ms	720 ms	1520 ms	0.66 Hz	2.94
15	10 μF	100 kΩ	1 MΩ	0.068 Hz	8.4 s	7.0 s	15.4 ms	0.065 Hz	4.41

3.2 Discussion

The observation table shows a close agreement between the theoretical and experimental values of frequency for the 555 timer operating in astable mode. It is evident that as the values of resistance (R_1, R_2) and capacitance (C_1) increase, the total time period increases, leading to a decrease in frequency.

For smaller capacitance values (e.g., $0.001\,\mu F$), the frequency is observed in the kHz range, whereas for larger capacitance values (e.g., $10\,\mu F$), the frequency reduces to the Hz range. The percentage error between theoretical and experimental values is generally small, indicating good agreement.

However, slight deviations are observed, which may be attributed to practical limitations such as component tolerances, measurement inaccuracies, and non-ideal behavior of the 555 timer IC. The duty cycle also varies slightly from the expected value due to unequal charging and discharging paths.

Overall, the experiment successfully verifies the theoretical concepts of the astable multivibrator using the 555 timer IC.

4 Sources of Error

4.1 Systematic Errors

1. Variation in supply voltage affecting the threshold levels of the IC.
2. Tolerance in resistor and capacitor values leading to deviation from expected results.
3. Calibration errors in measuring instruments such as CRO.

4. Non-ideal characteristics of the 555 timer IC.

5. Improper breadboard connections causing parasitic effects.

4.2 Random Errors

1. Loose or intermittent connections in the circuit.

2. Electrical noise and external interference affecting waveform stability.

3. Human error in reading measurements from CRO.

4. Contact resistance variations at junction points.

5. Environmental factors such as temperature and humidity.

5 Results

The 555 timer IC was successfully configured in astable mode to generate a continuous square wave output. The experimentally measured frequencies were found to be in close agreement with the theoretical values calculated using standard formulas. The relationship between frequency, resistance, and capacitance was verified, confirming that frequency decreases with an increase in R and C values.

6 Conclusion

The experiment demonstrates the operation of the 555 timer IC as an astable multivibrator. It confirms that the output frequency depends on the external resistors and capacitor connected to the circuit. The experimental results closely match theoretical predictions, validating the governing equations. The 555 timer proves to be a simple, reliable, and effective device for generating square wave signals in electronic circuits.

References

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