Experiment

Study of an astable multivibrator circuit using IC 555)

1 Objectives

To design and study of astable multivibrator circuits using IC 555.

2 Circuit components/equipment

1. IC 555 (1 No.)
2. Resistors (1 kΩ, 2 Nos; 10 kΩ, 2 Nos; 2.7 kΩ, 1 No)
3. Capacitors (0.01 μF, 0.047 μF, 0.1 μF, 1 μF; 1 No. each)
4. DC Power supply (0-30 V)
5. Oscilloscope
6. Connecting wires
7. Breadboard

3 Theory

Multivibrator

Individual Sequential Logic circuits can be used to build more complex circuits such as Counters, Shift Registers, Latches or Memories etc, but for these types of circuits to operate in a "Sequential" way, they require the addition of a clock pulse or timing signal to cause them to change their state. Clock pulses are generally square shaped waves that are produced by a single pulse generator circuit such as a Multivibrator which oscillates between a "HIGH" and a "LOW" state and generally has an even 50% duty cycle, that isit has a 50% "ON" time and a 50% "OFF" time. Sequential logic circuits that use theclock signal for synchronization may also change their state on either the rising or falling edge, or both of the actual clock signal. There are basically three types of pulse generation circuits depending on the number of stable states.

1. **Astable:** has NO stable states but switches continuously between two states thisaction produces a train of square wave pulses at a fixed frequency.

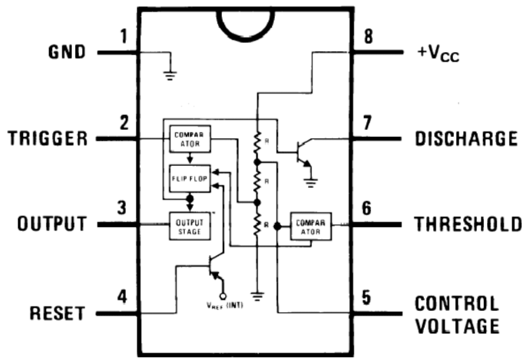
2. **Monostable:** has only ONE stable state and if triggered externally, it returns backto its first stable state.

3. **Bistable:** has TWO stable states that produces a single pulse either positive ornegative in value.

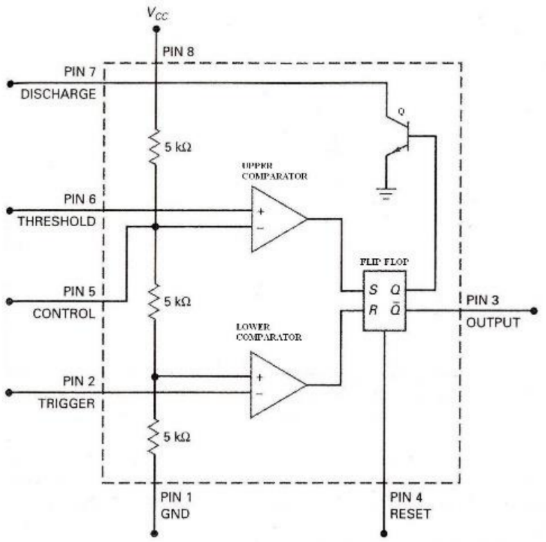
IC 555 timer

The 555 timer IC was first introduced around 1971 by the Signetics Corporation as the SE555/NE555 and was called "The IC Time Machine" and was also the very first and only commercial timer IC available. It provided circuit designers with a relatively cheap, stable, and user-friendly integrated circuit for timer and multivibrator applications. The IC comprises of 23 transistors, 2 diodes and 16 resistors with built-in compensation for component tolerance and temperature drift.

IC 555 in 8-pin DIP package & Functional block diagram of IC 555



(a)



(b)

The pin connections are as follows:

1. Ground.
2. Trigger input.
3. Output.
4. Reset input.
5. Control voltage.
6. Threshold input.
7. Discharge.
8. +VCC. +5 to +15 volts in normal use.

Pin 1: Ground. All voltages are measured with respect to this terminal.

Pin 2: Trigger. The output of the timer depends on the amplitude of the external trigger pulse applied to this pin. When a negative going pulse of amplitude greater than

1/3 V_{CC} is applied to this pin, the output of the timer high. The output remains high as long as the trigger terminal is held at a low voltage

Pin 3: Output. The output of the timer is measured here with respect to ground. There are two ways by which a load can be connected to the output terminal: either between pin 3 and ground or between pin3 and supply voltage $+V_{CC}$. When the output is low the load current flows through the load connected between pin 3 and $+V_{CC}$ into the output terminal and is called sink current. The current through the grounded load is zero when the outputis low. For this reason, the load connected between pin 3 and $+V_{CC}$ is called the normally on load (we will use this for our circuit) and that connected between pin 3 and ground is called normally off-load. On the other hand, when the output is high the current through the load connected between pin 3 and $+V_{CC}$ is zero. The output terminal supplies current to the normally off load. This current is called source current. The maximum value of sink or source current is 200 mA.

Pin 4: Reset. The 555 timer can be reset (disabled) by applying a negative pulse to this pin. When the reset function is not in use, the reset terminal should be connected to $+V_{CC}$ to avoid any possibility of false triggering.

Pin 5: Control Voltage. An external voltage applied to this terminal changes the thresholdas well as trigger voltage. Thus by imposing a voltage on this pin or by connecting a pot between this pin and ground, the pulse width of the output waveform can be varied. When not used, the control pin should be bypassed to ground with a 0.01 μF Capacitor to prevent any noise problems.

Pin 6: Threshold. When the voltage at this pin is greater than or equal to the threshold voltage 2/3 V_{CC}, the output of the timer low.

Pin 7: Discharge. This pin is connected internally to the collector of transistor Q. Whenthe output is high Q is OFF and acts as an open circuit to external capacitor C connected across it. On the other hand, when the output is low, Q is saturated and acts as a short circuit, shorting out the external capacitor C to ground.

Pin 8: $+V_{CC}$. The supply voltage of +5 V to + 18 V is applied to this pin with respect to ground.

Operation

The functional block diagram shows that the device consists of two comparators, three resistors and a flip-flop. A comparator is an OPAMP that compares an input voltage and indicates whether an input is higher or lower than a reference voltage by swinging into saturation in both the direction. The operation of the 555 timer revolves around the three resistors that form a voltage divider across the power supply to develop the reference voltage, and the two comparators connected to this voltage divider. The IC is quiescent so long as the trigger input (pin 2) remains at $+V_{CC}$ and the threshold input (pin 6) is at ground. Assume the reset input (pin 4) is also at $+V_{CC}$ and therefore inactive, and that the control voltage input (pin 5) is unconnected.

The three resistors in the voltage divider all have the same value (5k in the bipolar version of this IC and hence the name 555), so the trigger and threshold comparator reference voltages are 1/3 and 2/3 of the supply voltage, respectively. The control voltage input at pin 5 can directly affect this relationship, although most of the time this pin is unused. The internal flip-flop changes state when the trigger input at pin 2 is pulled down below $+V_{CC}/3$. When this occurs, the output (pin 3) changes state to $+V_{CC}$ and the discharge transistor (pin 7) is turned off. The trigger input can now return to $+V_{CC}$; it will not affect the state of the IC.

However, if the threshold input (pin 6) is now raised above $+(2/3)V_{CC}$, the output will return to ground and the discharge transistor will be turned on again. When the threshold input returns to ground, the IC will remain in this state, which was the original state when we started this analysis. The easiest way to allow the threshold voltage (pin 6) to gradually rise to $+(2/3)V_{CC}$ is to connect it externally to a capacitor being allowed tocharge through a resistor. In this way we can adjust the R and C values for almost anytime interval we might want.

IC 555 Timer as a multivibrator

The 555 can operate in either mono/bi-stable or astable mode, depending on the connections to and the arrangement of the external components. Thus, it can either produce a single pulse when triggered, or it can produce a continuous pulse train as longas it remains powered.

IC 555 Timer as an astable multivibrator

These circuits are not stable in any state and switch outputs after predetermined time periods. The result of this is that the output is a continuous square/rectangular wave with the properties depending on values of external resistors and capacitors. Thus, while designing these circuits following parameters need to be determined:

1. Frequency (or the time period) of the wave.
2. The duty cycle of the wave

Referring to Figure 2 of a rectangular waveform, the time period of the pulse is defined as T and duration of the pulse (ON time) is τ. Duty cycle can be defined as the ON time / Period i.e., τ/T in the above figure. Obviously, a duty cycle of 50% will yield a square wave.

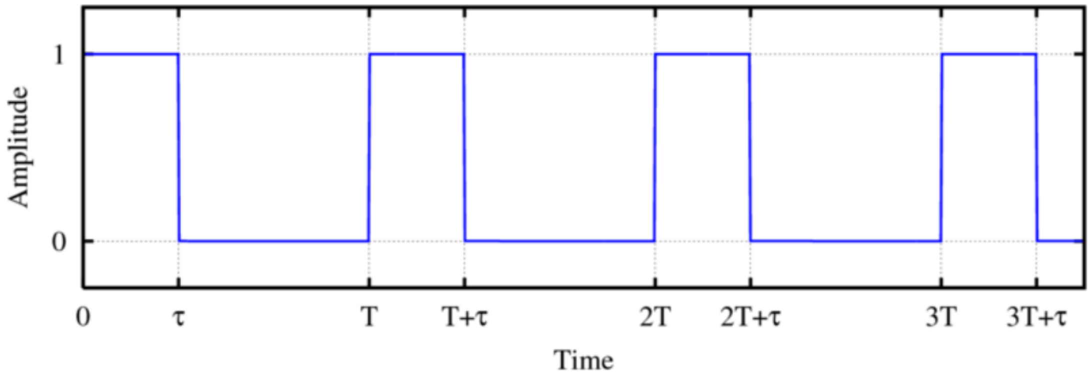


Figure 2: A rectangular waveform.

4 Circuit diagram

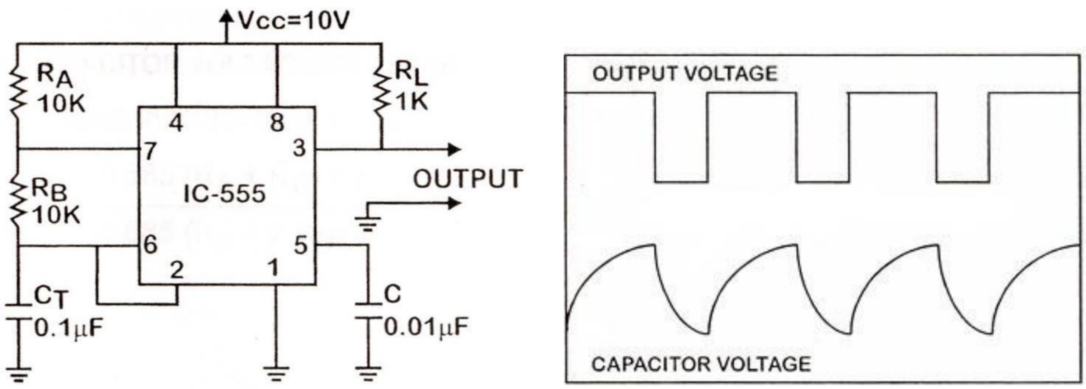


Figure 3: Circuit diagram and illustrated waveforms.

The key external component of the astable timer is the capacitor. An astable multivibrator can be designed as shown in the circuit diagram (with typical component values) using IC 555, for a duty cycle of more than 50%. The corresponding voltage across the capacitor and voltage at output is also shown. The astable function is achieved by charging/discharging a capacitor through resistors connected, respectively, either to V_{CC} or GND. Switching between the charging and discharging modes is handled by resistor divider $R_1 - R_3$, two Comparators, and an RS Flip-Flop in IC 555. The upper or lower comparator simply generates a positive pulse if V_C goes above $(2/3)V_{CC}$ or below $(1/3)V_{CC}$. And these positive pulses either SET or RESET the Q output.

The time for charging C from $(1/3)V_{CC}$ to $(2/3)V_{CC}$ i.e.,

$$\text{ON Time: } T_{\text{ON}} = 0.693(R_A + R_B)C_T.$$

The time for discharging C from $(2/3)V_{CC}$ to $(1/3)V_{CC}$, i.e.,

$$\text{OFF time: } T_{\text{OFF}} = 0.693 R_B C_T.$$

The total oscillation period is given by:

$$T_{\text{osc}} = 0.693(R_A + R_B)C_T + 0.693R_BC_T = 0.693(R_A + 2R_B)C_T$$

Thus

$$f_{\text{osc}} = \frac{1}{T_{\text{osc}}} = \frac{1.44}{(R_A + 2R_B)C_T}$$

$$\text{Duty cycle} = \frac{T_{\text{ON}}}{T_{\text{ON}} + T_{\text{OFF}}} \times 100\%$$

$$\text{Duty cycle} = \frac{R_A + R_B}{R_A + 2R_B} \times 100\%$$

5 Procedure

Astable multivibrator

For duty cycle more than 50%

1. Configure the circuit as per the circuit diagram.
2. Use $R_A = R_B = 10$ kΩ, $R_L = 1$ kΩ and $C_T = 0.1$ μF, $C = 0.01$ μF. Using the power supply set $V_{CC} = 5$ V.
3. Compute the expected values of f_{osc} and duty cycle (%).
4. Connect the output terminal (pin 3) to channel 1 of the oscilloscope. Also feed the voltage across capacitor to channel 2.
5. Power on your circuit and observe and save the output. Determine the values of f_{osc} and duty cycle (%) from your observations and compare with the theoretical values.
6. When you are done, turn off the power to your experimental circuit.

6 Observation

Astable Multivibrator

For duty cycle more than 50%

$R_A =$ ______ kΩ, $R_B =$ ______ kΩ, $C_T =$ ______ μF

Output waveform and capacitor voltage as observed in oscilloscope: (Fill data here)

Table 1: Observation table for oscillation frequency and duty cycle.

Parameters	Calculate value	Observed value	Error
f_{osc}			
Duty cycle (%)			

7 Results

8 Precautions

1. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.

2. Switch off the power supply after the experiment is completed.