Timer [IC 555]

The IC 555 is the most versatile linear integrated circuit introduced by signetics corporation. Fig. 1 shows the pin diagram and block diagram of NE 555 Timer. This is 8 pin IC timer.

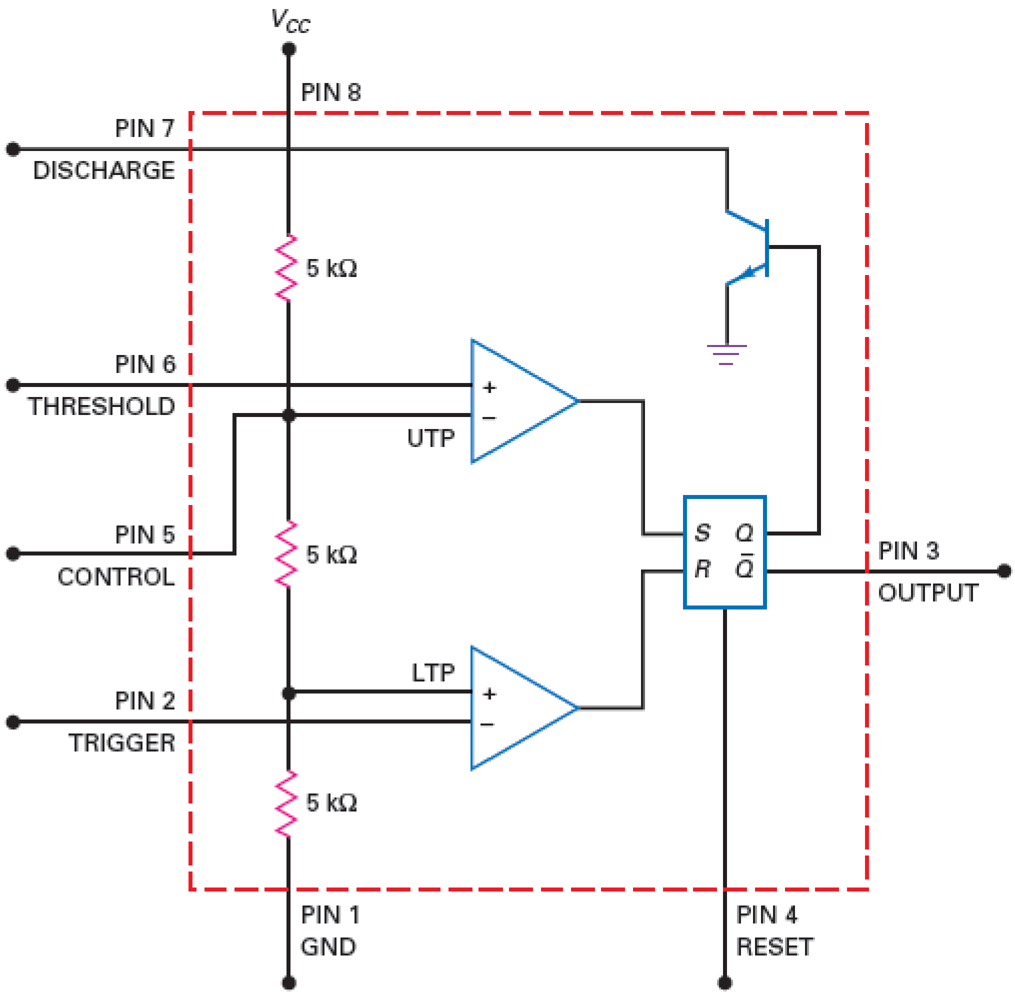


Fig.1

Function of Pins:

Pin 1: Ground

All the voltages are measured with respect to this terminal.

Pin 2: Trigger

The IC 555 uses two comparators. The voltage divider consists of three equal resistances (5kΩ each) Due to voltage divider, the voltage of non inverting terminal of lower comparator is fixed at 1/3 Vcc. The inverting input of comparator (lower) which is compared with 1/3 Vcc, is nothing but trigger input brought out as pin no. 2. When the trigger input is slightly less than 1/3 Vcc, the output of lower comparator goes high. This output is given to the RESET input of R-S flip-flop, so high output of lower comparator resets the flip-flop.

Pin 3: Output

The complementary single output $\bar{Q}$ of the flip-flop goes pin 3 which is the output.

Pin 4: RESET

This is an interrupt to the timing device. When pin 4 is grounded, it stops the working of the device and makes it off. Thus, pin 4 provides ON/OFF features to the IC 555. Normally pin 4 is connected to +Vcc.

Pin 5: CONTRL VOLTAGE INPUT

In most the applications, external control voltage is not used. This pin is nothing but the inverting input terminal of upper comparator. The voltage divider holds the voltage of this input at 2/3 Vcc. This is a reference level for upper comparator with which threshold is compared. If reference level required is other than 2/3 Vcc for upper comparator then external input is to be given to pin 5.

Pin 6: THRESHOLD

This is the non inverting input terminal at upper comparator. The external voltage is applied to this pin 6. When this voltage is more than 2/3 Vcc, the upper comparator output goes high. This is given to the set input of R-S flip-flop. Thus high output of upper comparator sets the flip-flop. This makes Q of flip-flop high and $\bar{Q}$ low. Thus the output of IC 555 at pin 3 goes low. Remember that output at pin 3 is $\bar{Q}$ which complementary output of flip-flop is.

In short,

For threshold $> \frac{2}{3}$Vcc, flip-flop $\rightarrow$ set, Q $\rightarrow$ high, output at pin 3 $\rightarrow$ low.

For trigger $> \frac{1}{3}$Vcc, flip-flop $\rightarrow$ reset, Q $\rightarrow$ low, output at pin 3 $\rightarrow$ High.

Pin 7: DISCHARGE

This pin is connected to the collector of the discharge transistor when Q is low, transistor Q is OFF. It acts as an open circuit to the external capacitor C to be connected across to be connected across it and it charges through external Resistor R.

When Q is high, transistor Q is ON. It acts as a short circuit, shorting the external capacitor C to be connected across it.

Pin 8: SUPPLY +Vcc

The IC 555 timer can work with any supply voltage between 4.5 V and +18V

MULTIVIBRATOR

A multivibrator is a two-state circuit that has zero, one or two stable output states. When the 555 timer is used in the mono-stable mode, it is called a monostable multi-vibrator because it has only one stable state.

The Bi-stable multivibrator has two stable stages. It requires an external trigger pulse to change from one stable state to other.

The Astable multivibrator has both the states as quasi-stable states. None of the states is stable state. This multivibrator does not require any external pulse for the transition, hence it is called tree running multivibrator.

Astable Multivibrator Using IC 555

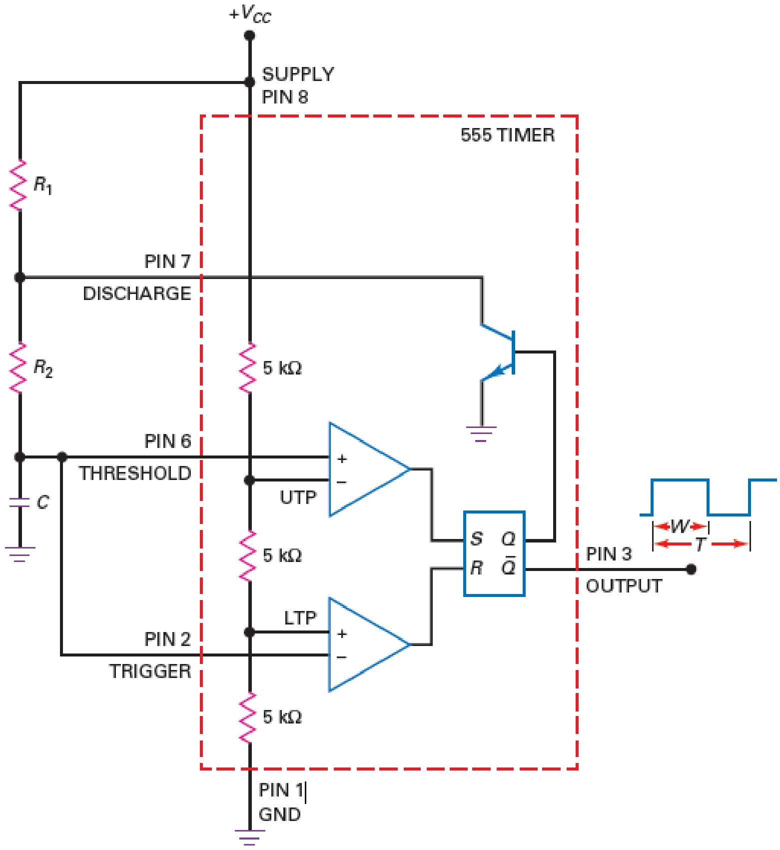


Fig 2

Fig 2 shows the IC 555 connected as on astable multivibrator. The threshold input is connected to the trigger input. Two external resistances R_1, R_2 and the capacitor C is used in the circuit. This circuit changes its state alternately. Hence the operation is also called as tree running multivibrator or oscillator

Operation:

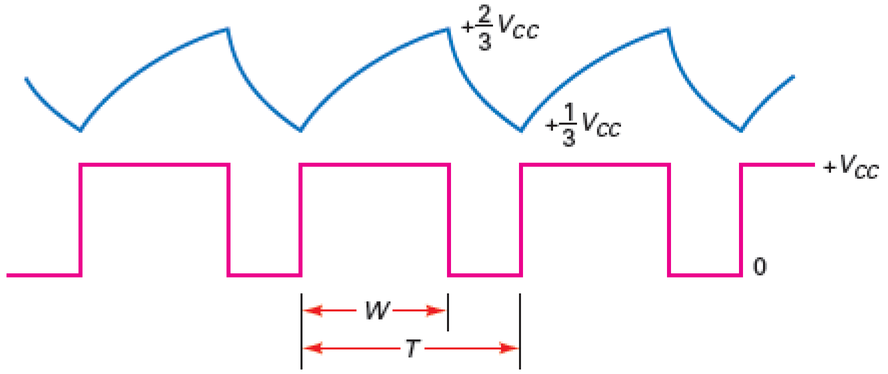
When the flip-flop is set, Q is high which drives the transistor in saturation and capacitor gets discharged. Now the capacitor voltage is nothing but the trigger voltage. So while discharging, when it becomes less than 1/3 Vcc, lower comparator output goes high. This resets the hence Q goes low and $\overline{Q}$ goes high.

When the flip-flop is reset, Q is low which makes transistor OFF. Thus capacitor starts charging through resistances R_1 and R_2 towards Vcc. As total resistance in the charging path is (R_1+R_2), the charging time constant is (R_1+R_2) C.

Now the capacitor voltage is also a threshold voltage. While charging, capacitor voltage increases i.e. threshold voltage increases. When it exceed 2/3 Vcc, then the output of upper comparator goes high which sets the flip-flop. The flip-flop Output Q becomes high and output at pin 3 i.e. $\overline{Q}$ becomes low.

High Q drives transistor Q in saturation and capacitor C starts discharging through resistance R_2. Thus the discharging time constant is R_2C. When capacitor voltages becomes less than 1/3 Vcc, lower comparator output goes high, resetting the flip-flop. This cycle repeats.

Thus when capacitor is charging, output is high while when it is discharging the output is low. The output is a rectangular ware. The capacitor voltage is exponentially rising and falling.

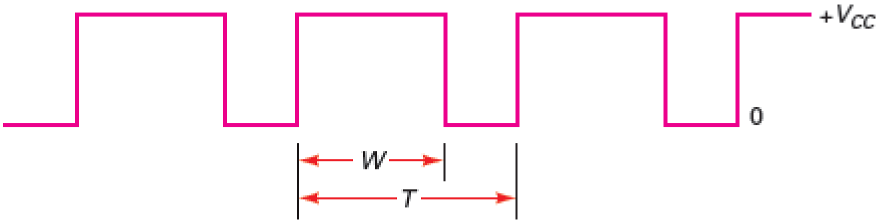


Duty Cycle:

Generally the charging time constant is greater than the discharging time constant. Hence at the output, the wave form is not symmetric. The high output remains longer period than low output.

The ratio of high output period and low output period is given by a mathematical operator called duty cycle.

Duty cycle is defined as the ratio of ON time i.e. high output to the total time at one cycle.



W = time for output is high

T = time of one cycle

$$D = \text{duty cycle} = \frac{W}{T}$$

$$\% D = \frac{W}{T} \times 100 \qquad \text{---------- [1]}$$

The charging time for the capacitor is given by

$$T_c = \text{charging time} = 0.693\,(R_1+R_2)\,C \qquad \text{---------[2]}$$

While the discharging time is given by

$$T_d = \text{discharging time} = 0.693\,R_2C \qquad \text{----------[3]}$$

Hence time for one cycle is

$$T = T_c+T_d = 0.693\,(R_1+R_2)\,C+0.693\,R_2C$$

$$T = 0.693\,(R_1+R_2)\,C \qquad \text{------------[4]}$$

While

$$W = T_c = 0.693\,(R_1+R_2)C$$

$$\therefore \quad \%D = \frac{W}{T} \times 100\% = \frac{0.693(R_1 + R_2)C}{0.693(R_1 + 2R_2)C} \times 100$$

$$\%D = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100 \qquad \text{------------[5]}$$

While the frequency of oscillation is given by

$$f = \frac{1}{T} = \frac{1}{0.693(R_1 + 2R_2)C} Hz$$

$$f = \frac{1.44}{(R_1 + 2R_2)C} Hz \qquad \text{------------[6]}$$

Schematic diagram –

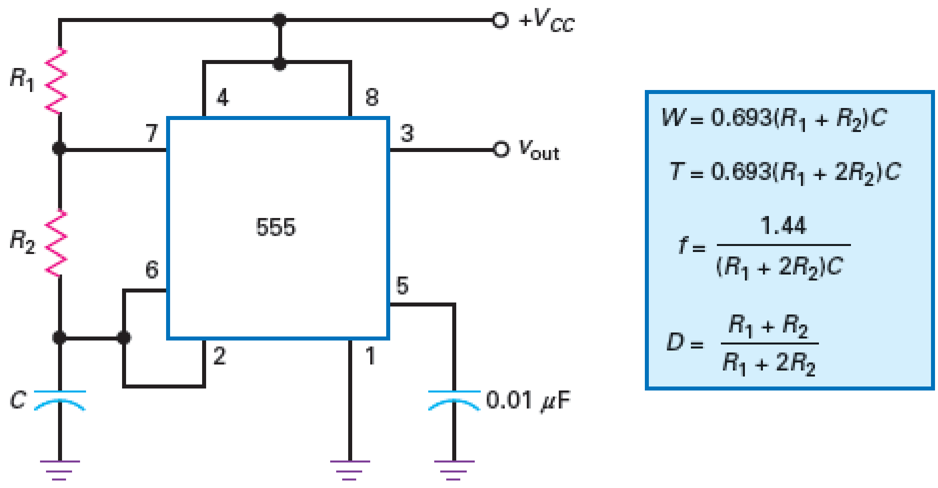


Fig. 3 shows the schematic diagram of astable multivibrator circuit. It shows only the external components R_1, R_2 and C. pin 4 is tied to pin 8 and pin 5 is grounded through a small (0.01 μ*f*) capacitor

Problem-

1) Draw the circuit diagram of an astable multivibrator to generate the output signal with frequency ot $1kH_z$ and the duty cycle of 75%

Solution : Given $t = 1kH_z$

$D = 75\% = 0.75$

Now

$$t = \frac{1.44}{(R_1 + 2R_2)C} H_2 \quad \text{-------------1}$$

$$1 \times 10^3 = \frac{1.44}{(R_1 + 2R_2)C}$$

$$\therefore (R_1 + 2R_2)C = \frac{1.44}{1 \times 10^3} = 1.44 \times 10^{-3} \quad \text{-------2}$$

While

$$\%D = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100$$

$$0.75 = \frac{R_1 + R_2}{R_1 + 2R_2}$$

$$\therefore \quad (R_1 + 2R_2) = \frac{R_1 + R_2}{0.75} = 1.33(R_1 + R_2)$$

$$\therefore \quad R_1 + 2R_2 = 1.33(R_1 + R_2)[\ ]$$

$$R_1 + 2R_2 = 1.33R_1 + 1.33R_2$$

$$2R_1 - 1.33R_2 = 1.33R_1 - R_1$$

$$0.66R_2 = 0.33R_1$$

$$R_2 = \frac{0.33R_1}{0.66}$$

$$R_2 = 0.5R_1 \text{ ------------3}$$

From equation 2 and choosing C = 0.1μF

$$(R_1 + 2 \times 0.5R_1) \times 0.1 \times 10^{-6} = 1.44 \times 10^{-3}$$

$$2R_1 = \frac{1.44 \times 10^{-3}}{0.1 \times 10^{-6}}$$

$$2R_1 = 14.4 \times 10^3$$

$$R_1 = 7.2k\Omega$$

$$R_1 = 7.2k\Omega \quad \text{-------------4}$$

From equation 3

$$R_2 = 0.5R_1$$

$$\therefore \quad R_2 = 0.5 \times 7.2 \times \Omega$$

Required components are

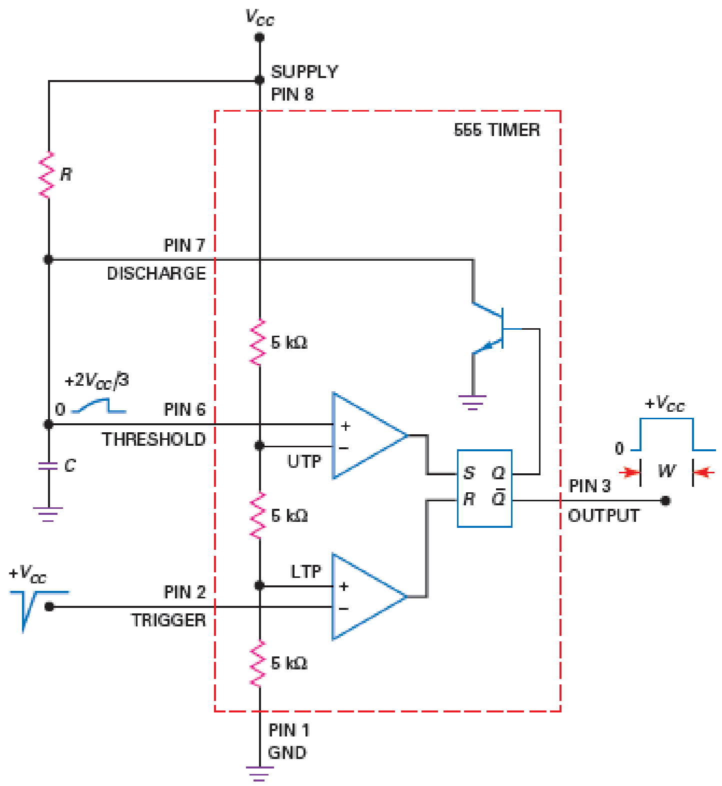
$$R_2 = 3.6k\,\Omega \quad \text{-------------5}$$

$$\therefore \quad R_1 = 7.2k\Omega, \quad R_2 = 3.6k\Omega, \quad c = 0.1\mu F$$

Monostable Multivibrator Using IC 555:

The IC 555 timer can be operated as a monostable multivibrator by connecting external resistor and capacitor as shown in Fig.

The circuit has only one stable state. When trigger is applied, it produces a pulse at the output and returns back to its stable state. The duration of the pulse depends on the values of the R and C. As it has only one stable state, it is called one shot multivibrator.



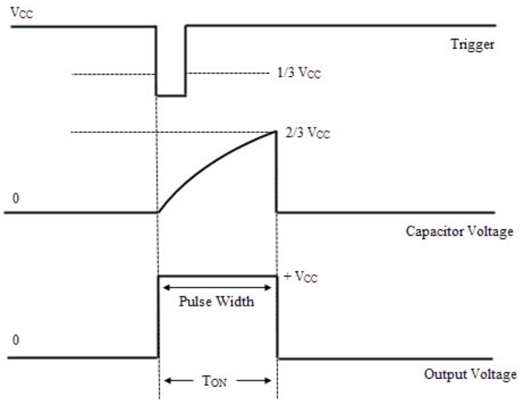
Operation:

The flip-flop is initially set i.e. Q is high. This drives the transistor in saturation. The capacitor charges completely and voltage across it nearly zero. The output at pin 3 is low.

When a trigger input, a low going pulse is applied, then circuit state remains unchanged trigger voltage is greater than 1/3 Vcc. When it becomes less than 1/3 Vcc, then lower comparator output goes high. This resets the flip-flop so Q low and $\bar{Q}$ goes high. Low $\bar{Q}$ makes the transistor OFF. Hence capacitor C starts charging through resistor R.

The voltage across capacitor increases exponentially. This voltage is nothing but threshold voltage at pin 6. When this voltage becomes more than 2/3 Vcc. Then upper comparator output goes high. This sets the flip-flop i.e. Q becomes high and $\overline{Q}$ low. This high Q drives the transistor in saturation. Thus capacitor quickly discharges.

Thus V_{out} at pin 3 is low at start, when trigger becomes less than 1/3 Vcc it becomes high and when threshold is greater than 2/3 Vcc again it becomes low, till next trigger pulse occurs. A rectangular wave (pulse) is produced at the output. The pulse width of this wave is controlled the charging time of capacitor. This depends on the time constant RC control the pulse width. The waveforms are shown in following figure.



Derivation of Pulse Width:

The voltage across capacitor increases exponentially and is given by

$$V_c = V\left(1 - e^{-t/Rc}\right) \qquad 1$$

$$V_c = 2/3Vcc$$

$$2/3\,Vcc = Vcc\left(1 - e^{-t/Rc}\right)$$

$$2/3 = \left(1 - e^{-t/Rc}\right)$$

$$2/3 - 1 = 1 - e^{-t/Rc}$$

$$-1/3 = e^{-t/Rc}$$

$$1/3 = e^{-t/Rc}$$

$$-t/Rc = l_n(0.333) \qquad \therefore 1/3 = 0.333$$

$$-t/Rc = -1.0986$$

$$t = 1.0986\,RC$$

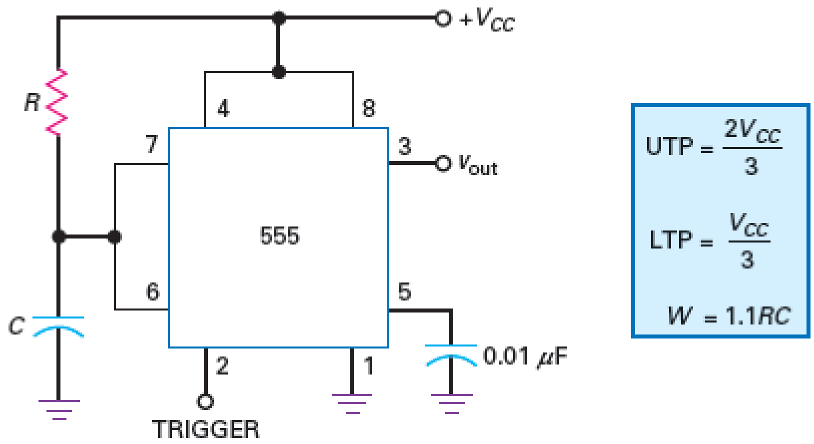
$$t = 1.1RC \qquad \text{-------} \quad 2$$

Where C is in farad, R is in ohm and t is in sec. Thus, we can say that voltage across capacitor will reach 2/3 Vcc in approx 1.1 times, time constant i.e.1.1 RC.

Thus the pulse width denoted by W is

$$W = 1.1RC \qquad \text{-----} \quad 3$$

Schematic Diagram – Generally a schematic diagram of the IC 555 circuit is shown which does not include comparators, flip-flop etc. It only shows external components to be connected to the 8 pins of 555 figure shows schematic diagram of monostable multivibrator using IC555.



The external components R and C are shown. To avoid accidental reset, pin 4 is connected to pin 8 which is supply + Vcc. To have the noise filtering of control Voltage, the pin 5 is grounded through a small capacitor of 0.01 μf.

Problem

Design a monostable for a pulse width of 10ms by using IC 555.

Solution

The required pulse with is w = 10 ms

The pulse with is given by

$$W = 1.1\ RC$$

$$10 \times 10^{-3} = 1.1\ RC$$

$$RC = 90.909 \times 10^{-3}$$

Chose $C = 0.1\ \mu f$

$$R = 90.909\ k^{\Omega}$$

$$= 91\ k\Omega$$