555 Timer

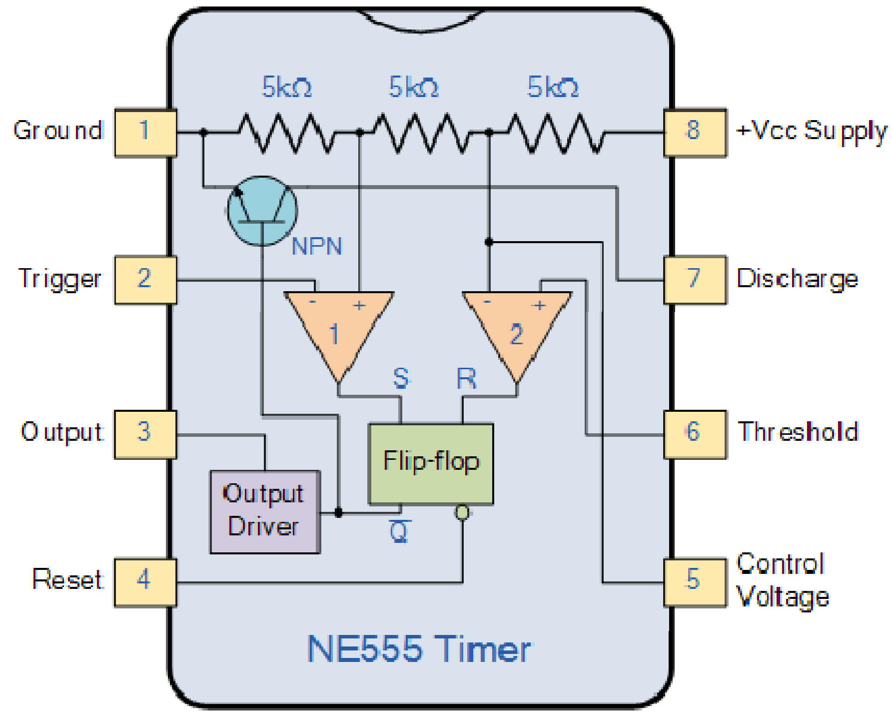
- IC's especially are designed to accurately produce the required output waveform with the addition of just a few extra timing components.
- One such device is the **555 Timer Oscillator** which is more commonly called the **"555 Timer"**
- The basic **555 timer** gets its name from the fact that there are three internally connected 5kΩ resistors which it uses to generate the two comparators reference voltages.
- The 555 timer IC is a very cheap, popular and useful precision timing device which can act as either a simple timer to generate single pulses or long time delays, or as a relaxation oscillator producing a string of stabilized waveforms.

555 Timer

- The 555 timer chip is extremely robust and stable 8-pin device that can be operated as a very accurate Monostable, Bistable or Astable Multivibrator:
- To produce a variety of applications such as one-shot or delay timers, pulse generation, LED and lamp flashers, alarms and tone generation, logic clocks, frequency division, power supplies and converters etc.
- The single 555 Timer chip in its basic form is a Bipolar 8-pin mini Dual-in-line Package (DIP) device consisting of "25 transistors, 2 diodes and about 16 resistors" arranged to form two comparators, a flip-flop and a high current output stage.

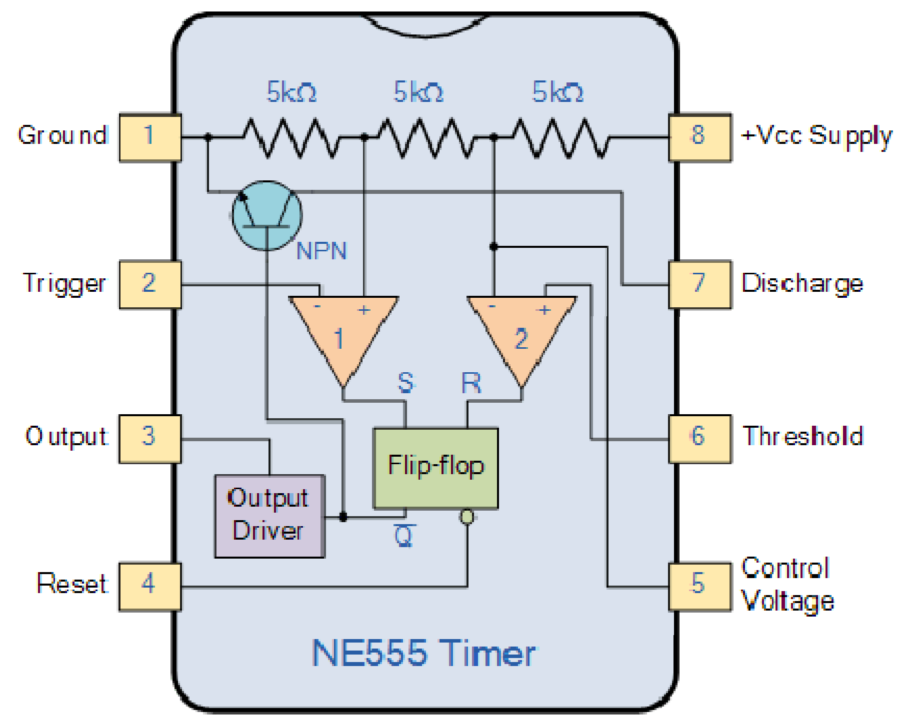
555 Timer Block Diagram

- Pin 1. – **Ground**, The ground pin connects the 555 timer to the negative (0v) supply rail.
- Pin 2. – **Trigger**, The negative input to comparator No 1. A negative pulse on this pin “sets” the internal Flip-flop when the voltage drops below 1/3Vcc causing the output to switch from a “LOW” to a “HIGH” state.
- Pin 3. – **Output**, The output pin is capable of sourcing or sinking up to 200mA of current at an output voltage so small speakers, LEDs or motors can be connected directly to the output.
- Pin 4. – **Reset**, This pin is used to “reset” the internal Flip-flop controlling the state of the output, pin 3. This is an active-low input and is generally connected to a logic “1” level when not used to prevent any unwanted resetting of the output.



555 Timer Block Diagram

- Pin 5. – **Control Voltage**, This pin controls the timing of the 555 by overriding the 2/3Vcc level of the voltage divider network. By applying a voltage to this pin the width of the output signal can be varied independently of the RC timing network. When not used it is connected to ground via a 10nF capacitor to eliminate any noise.
- Pin 6. – **Threshold**, The positive input to comparator No 2. This pin is used to reset the Flip-flop when the voltage applied to it exceeds 2/3Vcc causing the output to switch from "HIGH" to "LOW" state. This pin connects directly to the RC timing circuit.
- Pin 7. – **Discharge**, The discharge pin is connected directly to the Collector of an internal NPN transistor which is used to "discharge" the timing capacitor to ground when the output at pin 3 switches "LOW".
- Pin 8. – **Supply +Vcc**, This is the power supply pin and for general purpose TTL 555 timers is between 4.5V and 15V.

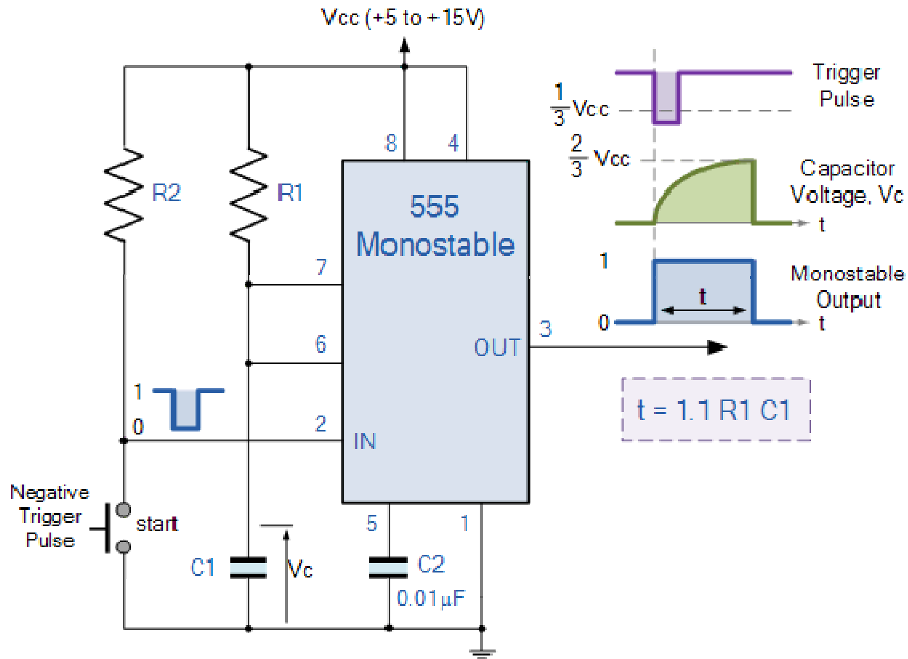


555 Timer Basic Operation

- The **555 Timers** name comes from the fact that there are three 5kΩ resistors connected together internally producing a voltage divider network between the supply voltage at pin 8 and ground at pin 1.
- The voltage across this series resistive network holds the inverting input of comparator two at 2/3Vcc and the non-inverting input to comparator one at 1/3Vcc.
- The two comparators produce an output voltage dependent upon the voltage difference at their inputs which is determined by the charging and discharging action of the externally connected RC network.
- The outputs from both comparators are connected to the two inputs of the flip-flop which in turn produces either a "HIGH" or "LOW" level output at Q based on the states of its inputs.
- The output from the flip-flop is used to control a high current output switching stage to drive the connected load producing either a "HIGH" or "LOW" voltage level at the output pin.

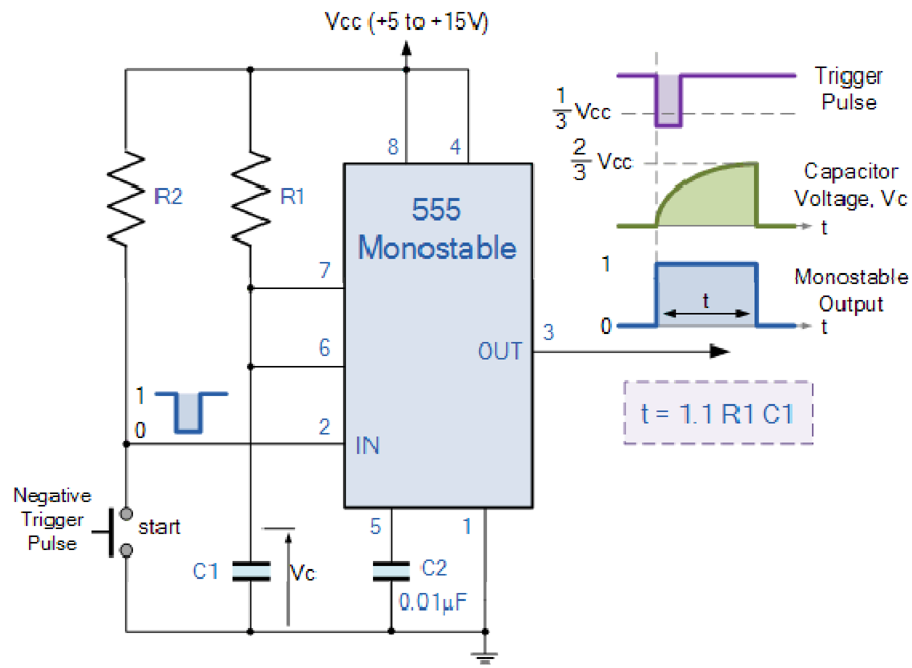
Monostable multivibrator using 555 timer

- This is the basic mode of operation of the IC 555. It requires only two extra components to make it work as a monostable multivibrator: a resistor and a capacitor.
- When a negative (0V) pulse is applied to the trigger input (pin 2) of the Monostable configured 555 Timer oscillator, the internal comparator, (comparator No1) detects this input and “sets” the state of the flip-flop, changing the output from a “LOW” state to a “HIGH” state.
- This action in turn turns “OFF” the discharge transistor connected to pin 7, thereby removing the short circuit across the external timing capacitor, C1.



Monostable Operation

- This action allows the timing capacitor to start to charge up through resistor, R1 until the voltage across the capacitor reaches the threshold (pin 6) voltage of 2/3Vcc set up by the internal voltage divider network.
- At this point the comparators output goes "HIGH" and "resets" the flip-flop back to its original state which in turn turns "ON" the transistor and discharges the capacitor to ground through pin 7.
- This causes the output to change its state back to the original stable "LOW" value awaiting another trigger pulse to start the timing process over again.
- Then as before, the Monostable Multivibrator has only "ONE" stable state.



Time period

- The **Monostable 555 Timer** circuit triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully.
- Once triggered, the 555 Monostable will remain in this “HIGH” unstable output state until the time period set up by the R_1 x C_1 network has elapsed.
- The amount of time that the output voltage remains “HIGH” or at a logic “1” level, is given by the following time constant equation.

$$\tau = 1.1 R_1 C_1$$

Pulse Width Calculation

- The voltage across the capacitor is,

$$v_c = V_f + \left(V_i - V_f\right)e^{-t/R_1C_1}$$

- V_f = +V_{CC}, V_i = 0 V, and the capacitor is charging to V_c = 2/3(V_{cc}):

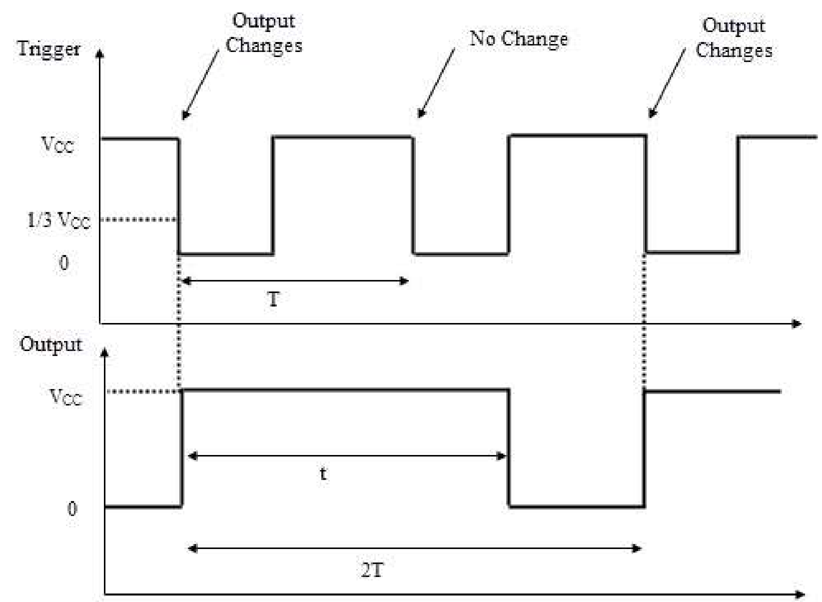
$$\frac{2}{3}V_{CC} = V_{CC} - V_{CC}e^{-t/R_1C_1}$$

$$\frac{2}{3} = 1 - e^{-t/R_1C_1} \qquad e^{-t/R_1C_1} = 1 - \frac{2}{3} = \frac{1}{3}$$

$$-t / R_1C_1 = \ln\left(\frac{1}{3}\right) = -1.098 \qquad t = 1.1R_1C_1$$

Frequency Divider: Application of Monostable Multivibrator

- When the IC 555 is used as a monostable multivibrator, a positive going rectangular pulse is available at the output when a negative going pulse of short duration is applied at the trigger input.
- By adjusting the time interval t of the charging or timing circuit the device can be made to work as a Frequency Divider circuit.
- If the timing interval t is made slightly larger than the time period of the input pulse (trigger pulse), the device can act as a Divide – by – two circuit.
- The timing interval can be controlled by appropriately choosing the values of the resistor R and the capacitor C in the timing circuit. The waveforms of the input and output signals corresponding to the divide–by–two circuit are shown here.
- The circuit will trigger for the first negative pulse of the trigger input. As a result, the output will go to high state. The output will remain high for the time interval t.
- During this interval, even if a second negative going trigger pulse is applied, the output will not be affected and continues to remain high as the timing interval is greater than the time period of the trigger pulse. On the third negative going trigger pulse, the circuit is retriggered.

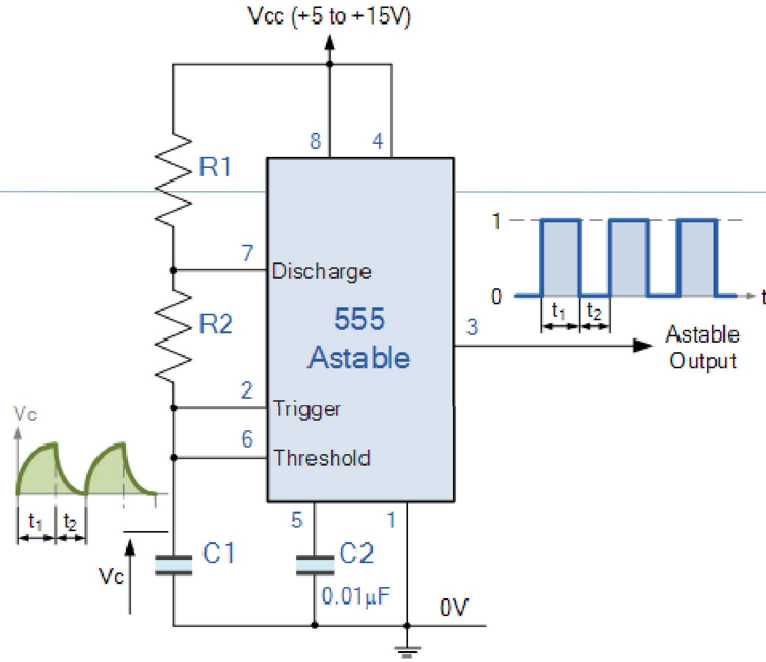


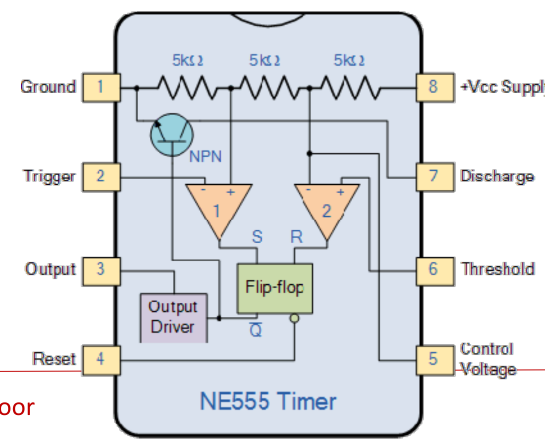
555 Timer: Astable Multivibrator

- The **555 Timer IC** can be connected in its Monostable mode thereby producing a precision timer of a fixed time duration
- the 555 timer IC in an Astable mode to produce a very stable **555 Oscillator** circuit for generating highly accurate free running waveforms whose output frequency can be adjusted by means of an externally connected RC tank circuit consisting of just two resistors and a capacitor.
- It has no stable states as it continuously switches from one state to the other

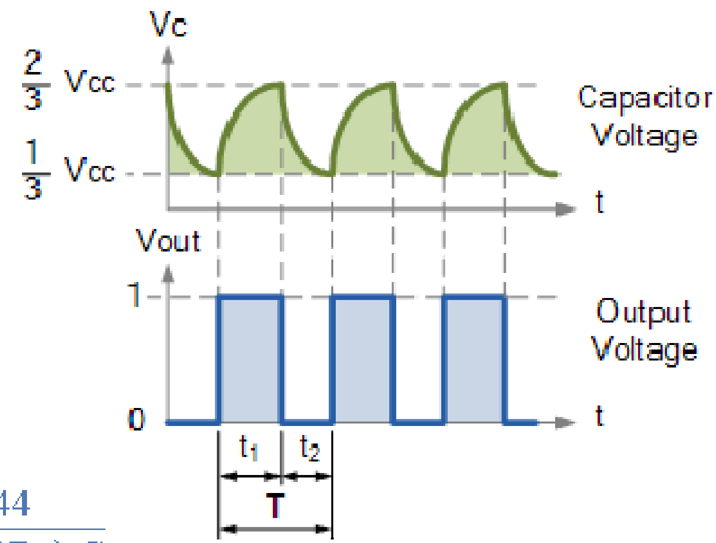
Operation

- In the **555 Oscillator** circuit, pin 2 and pin 6 are connected together allowing the circuit to re-trigger itself on each and every cycle allowing it to operate as a free running oscillator.
- During each cycle capacitor, C charges up through both timing resistors, R1 and R2 but discharges itself only through resistor, R2 as the other side of R2 is connected to the *discharge* terminal, pin 7.
- Then the capacitor charges up to 2/3Vcc (the upper comparator limit) which is determined by the (R1+R2) combination and discharges itself down to 1/3Vcc (the lower comparator limit) determined by the R2.
- This results in an output waveform whose output “ON” and “OFF” time periods are determined by the capacitor and resistors combinations.





Time period



- Charging time (t1) and discharge time (t2):

$$t_1 = 0.693(R_1 + R_2).C$$

and

$$t_2 = 0.693 \times R_2 \times C$$

- Total time period and frequency:

$$T = t_1 + t_2 = 0.693(R_1 + 2R_2).C \qquad f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2).C}$$

- Duty cycle:

$$\text{Duty Cycle} = \frac{T_{ON}}{T_{OFF} + T_{ON}} = \frac{R_1 + R_2}{(R_1 + 2R_2)}\ \%$$

Example:

- An **Astable 555 Oscillator** is constructed using the following components, R1 = 1kΩ, R2 = 2kΩ and capacitor C = 10uF. Calculate the output frequency from the 555 oscillator and the duty cycle of the output waveform.

t_1 – capacitor charge “ON” time is calculated as:

$$t_1 = 0.693(R_1 + R_2).C$$
$$= 0.693(1000 + 2000) \times 10 \times 10^{-6}$$
$$= 0.021s = 21ms$$

t_2 – capacitor discharge “OFF” time is calculated as:

$$t_2 = 0.693\,R_2.C$$
$$= 0.693 \times 2000 \times 10 \times 10^{-6}$$
$$= 0.014s = 14ms$$

$$T = t_1 + t_2 = 21ms + 14ms = 35ms$$

$$f = \frac{1}{T} = \frac{1}{35ms} = 28.6Hz$$

Giving a duty cycle value of:

$$\text{Duty Cycle} = \frac{R_1 + R_2}{(R_1 + 2R_2)} = \frac{1000 + 2000}{(1000 + 2 \times 2000)} = 0.6 \text{ or } 60\%$$

As the timing capacitor, C charges through resistors R1 and R2 but only discharges through resistor R2 the output duty cycle can be varied between 50 and 100% by changing the value of resistor R2. By decreasing the value of R2 the duty cycle increases towards 100% and by increasing R2 the duty cycle reduces towards 50%.