555 Timer IC

IC 555 timer is a one of the most widely used IC in electronics and is used in various electronic circuits for its robust and stable properties. The IC is used in a variety of timer, pulse generation, and oscillator applications. The 8-pin 555 Timer IC is one of the commonly used IC among students and hobbyists.

The 555 timer works as square-wave form generator with duty cycle varying from 50% to 100%, Oscillator and can also provide time delay in circuits. The 555 timer got its name from the three 5k ohm resistor connected in a voltage-divider pattern which is shown in the figure below. A simplified diagram of the internal circuit is given below for better understanding as the full internal circuit consists of over more than 16 resistors, 25 transistors, 2 diodes, a flip-flop and many other circuit components.

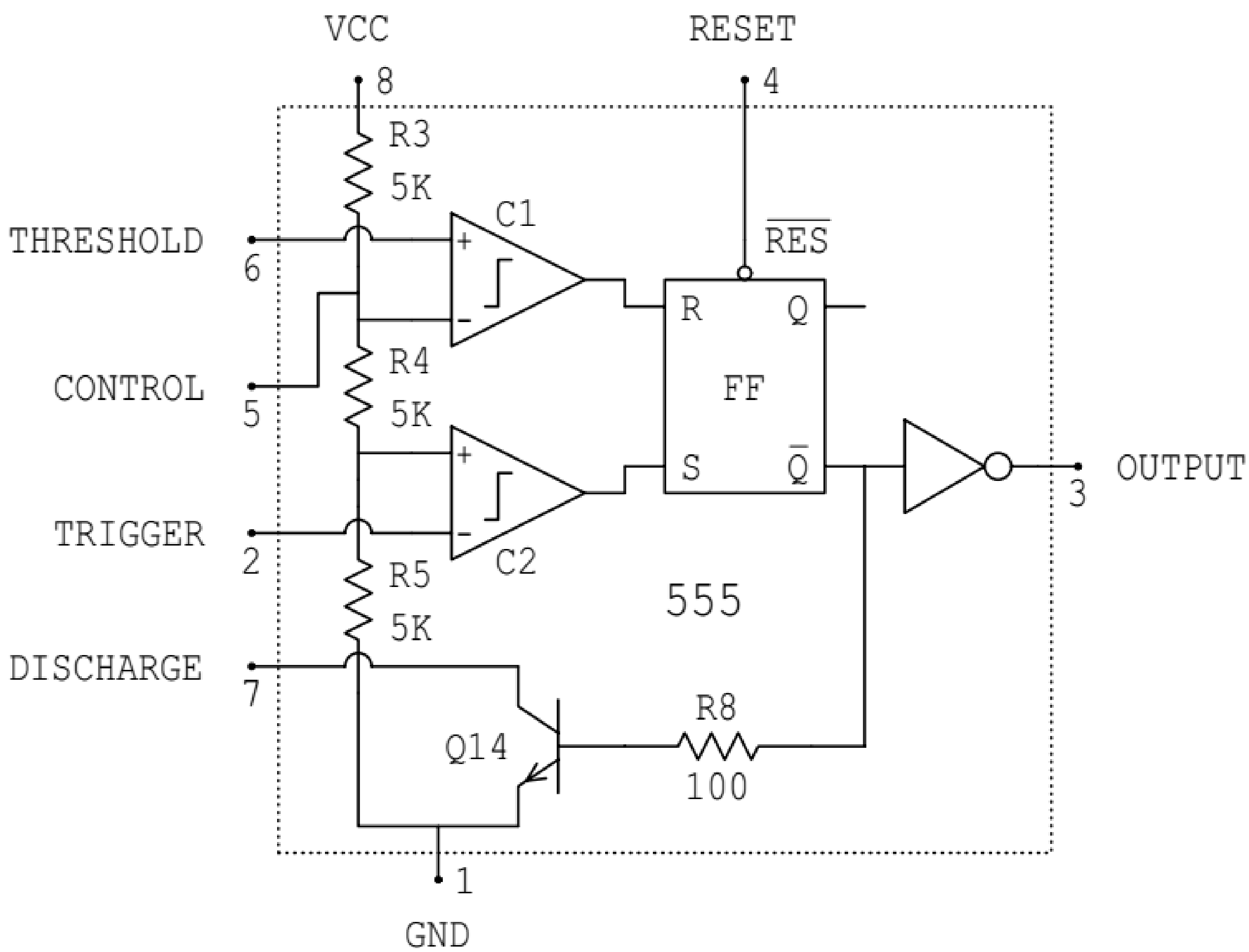


Figure 1: Functional block diagram of the 555 integrated-circuit timer.

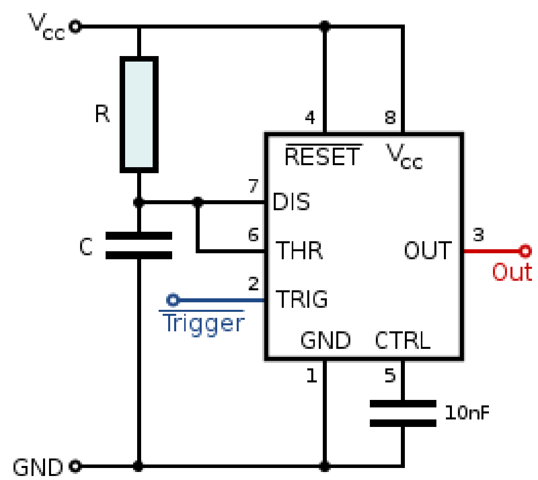
Some applications for the 555 Timer include:

- Ramp and Square wave generator
- Frequency dividers
- Voltage-controlled oscillators
- Pulse generators and LED flashers
- Time Delay Generation
- Pulse Width Modulation & Pulse Position Modulation

The 555 timer has essentially two modes of operation:

- Astable (free running) multivibrator and
- Monostable (one shot) multivibrator

Monostable operation



The circuit connection for the monostable operation is shown in Figure. 2. The corresponding waveforms are shown in Figure. 3. Initially, the TRIGGER input voltage is above the trigger level. Therefore, the flip-flop is reset, Q is high, OUTPUT is low, and the discharge transistor Q_{14} is on. Since Q_{14} is on, and the DISCHARGE pin is connected to the THRESHOLD input, the capacitor C is discharged. The THRESHOLD voltage is equal to the saturation V_{CES} voltage of the discharge transistor Q_{14}, which is close to zero. Note that the CONTROL input is left open so that the trigger and the threshold levels are $V_L = V_{CC}/3$ and $V_H = 2V_{CC}/3$. Note also that the RESET input is high (tied to V_{CC}) so that the timer operation is enabled. At $t = t_0$, a short pulse takes the TRIGGER input below the trigger level. This sets the flip-flop, the OUTPUT goes high, and the discharge transistor Q_{14} is turned off. Since Q_{14} is off, the capacitor C starts to charge up through the resistor R toward V_{CC}. After the interval Tw, the capacitor voltage reaches the threshold level $V_H = 2V_{CC}/3$, the flip-flop is reset, the output returns to low, and the discharge transistor Q_{14} is turned on again. When Q_{14} is turned on, its collector current quickly discharges the capacitor toward zero, and the circuit is again in the initially assumed steady state. Another short pulse on the TRIGGER input would be needed to produce another output pulse of duration Tw. Without the external trigger input, the output always stays low, which is why the circuit is called monostable, or one-shot.

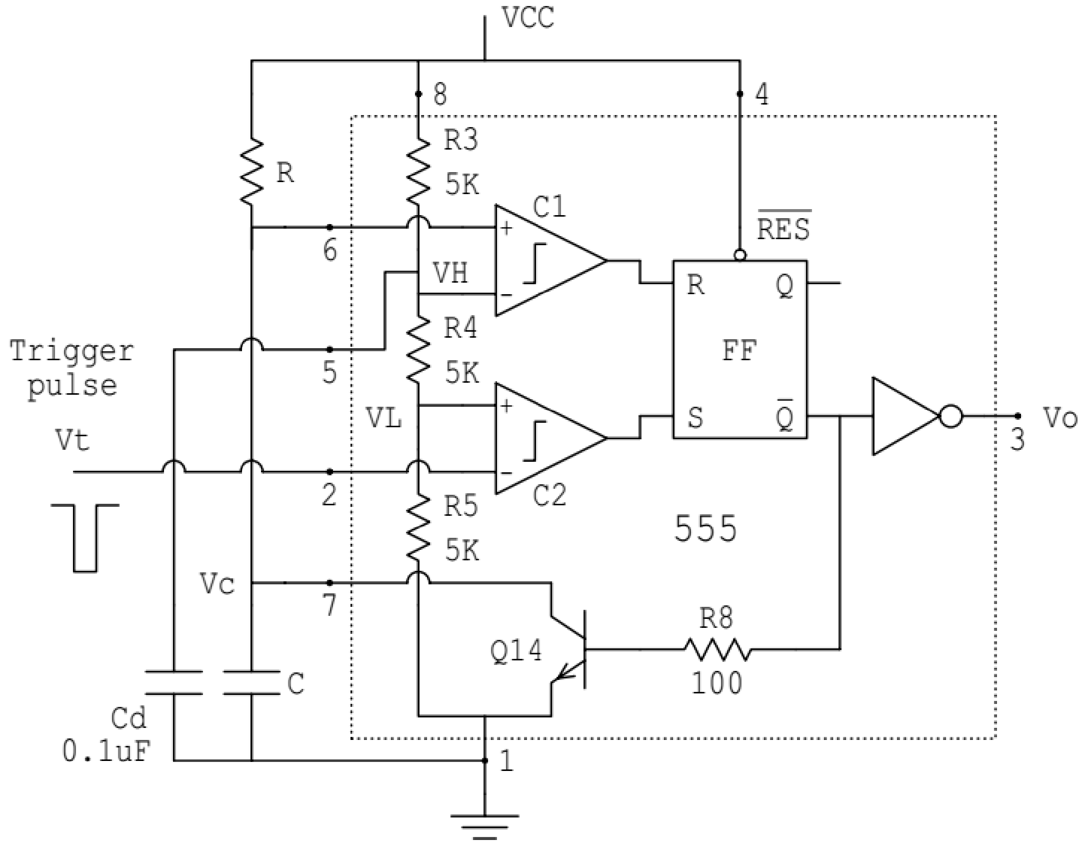


Figure 2: Monostable circuit built around the 555 timer.

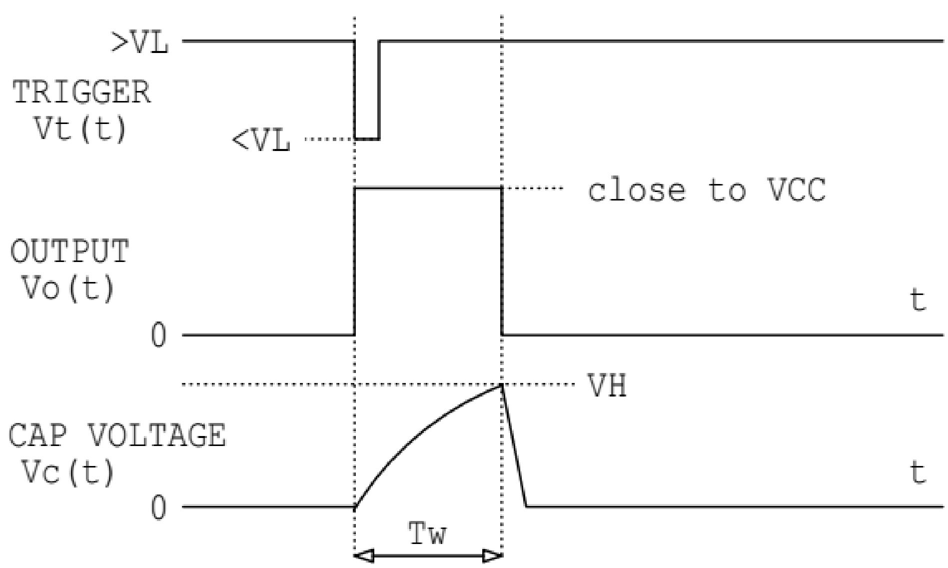


Figure 3: Typical waveforms in the monostable circuit with the 555 timer.

The charge equation for a RC one shot is:

$$\frac{2}{3}V_{CC} = V_{CC} - (V_{CC} - 0)e^{-t/RC}$$

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

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

$$-\frac{1}{3} = -e^{-t/RC}$$

$$\frac{1}{3} = e^{-t/RC}$$

$$\ln\left(\frac{1}{3}\right) = \ln\left(e^{-t/RC}\right)$$

$$-1.1 = -t/RC$$

$t = 1.1RC$ (pulse width T_w = t):

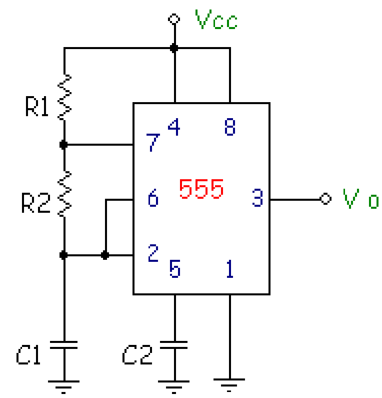
<u>Problem:</u> In the monostable multivibrator R=100kΩ and the time delay T=100ms. Calculate the value of C.

<u>Solution:</u>

T=1.1RC

$$\Rightarrow C = \frac{T}{1.1R} = \frac{100x10^{-3}}{1.1x100x10^{-3}} = 0.9\mu F$$

Astable operation:



With the addition of an external capacitor and two external resistors, the 555 can be configured to produce a periodic pulsating waveform at the output, without any external trigger pulses. The basic configuration for the astable operation is shown in right figure, together with typical steady-state waveforms in Figure. 6. The key difference between the monostable and the astable operation is that the TRIGGER input is connected together with the THRESHOLD input so that the timer triggers itself during operation. The capacitor C is periodically charged and discharged between the trigger level $V_L = V_{CC}/3$ and the threshold level $V_H = 2_{VCC}/3$. Suppose that at t = 0 the output is high, and the discharge transistor Q_{14} is off. The capacitor is charged through R_A and R_B until the capacitor voltage reaches $V_H = 2V_{CC}/3$ at $t = t_H$. At this point, the flip-flop is reset, the output goes low, and the discharge transistor Q_{14} is turned on. As a result, C is discharged through R_B and the saturated discharge transistor Q_{14}. At $t = t_H + t_L = Tp$, the capacitor voltage drops to $V_L = V_{CC}/3$, the flip-flop is set again, the output voltage goes high and the discharge transistor is turned off, starting another period.

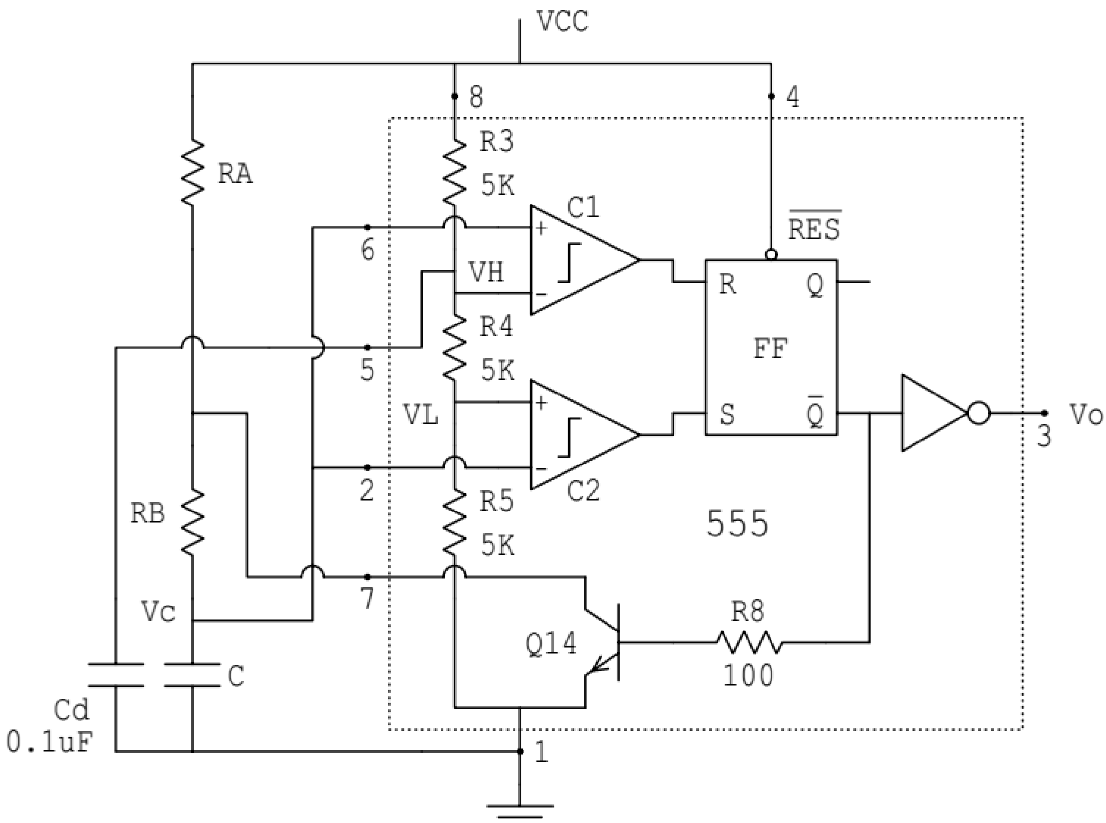


Figure 5: Astable circuit (pulse generator) built around the 555 timer.

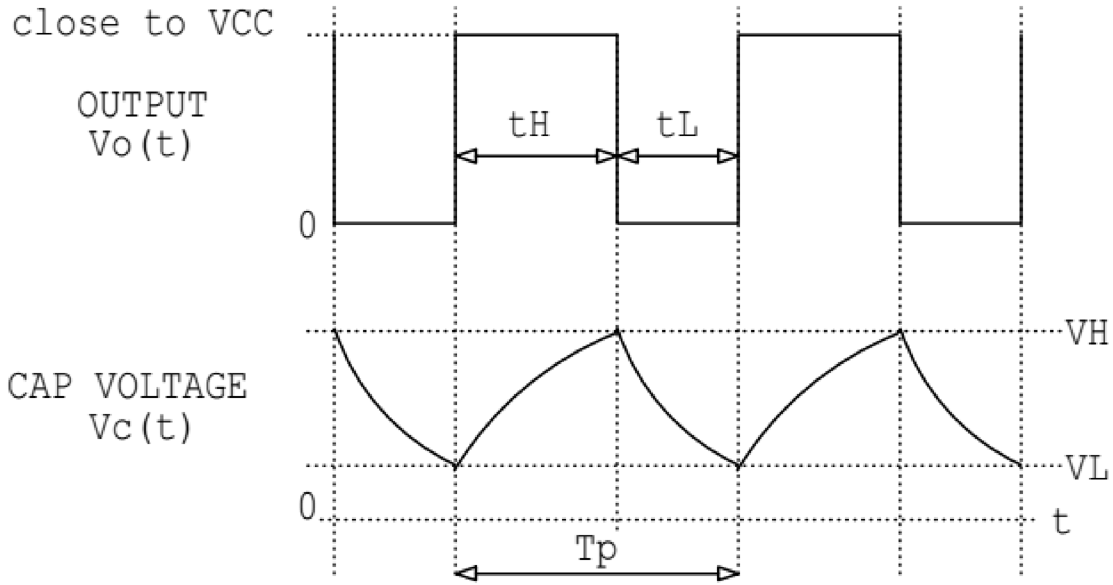


Figure 6: Typical waveforms in the astable circuit with the 555 timer.

Astable Multivibrator- Analysis

The capacitor voltage for a RC circuit connected with a input of V**cc** volts is given by,

$$v_c = V_{CC}(1 - e^{-t/RC})$$

The time t_1 taken by the circuit to change from 0 to 2V**cc**/3 is,

$$\frac{2V_{CC}}{3} = V_{CC}(1 - e^{-t1/RC}) \Rightarrow t_1 = 1.09RC$$

The time t**2** to charge from 0 to v**cc**/3 is

$$\frac{V_{CC}}{3} = V_{CC}(1 - e^{-t2/RC}) \Rightarrow t_2 = 0.405RC$$

So the time to change from V**cc**/3 to 2V**cc**/3 is,

$$t_{HIGH} = t_1 - t_2 = 1.09RC - 0.405RC = 0.69RC$$

So, for the given circuit,

$$t_{HIGH} = 0.69(R_A + R_B)C$$

The output is low while the capacitor discharges from 2V**cc**/3 to V**cc**/3 and the voltage across the capacitor is given by,

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

After solving, we get, t=0.69RC

For the given circuit,

$$t_{LOW} = 0.69\, R_B C$$

Both $R_\mathbf{A}$ and $R_\mathbf{B}$ are in the charge path, but only $R_\mathbf{B}$ is in the discharge path.

The total time period,

$$T = t_{HIGH} + t_{LOW} = 0.69\,(R_A + R_B)C + 0.69\, R_B C$$

$$\Rightarrow T = 0.69[(R_A + R_B)C + R_B C] = 0.69(R_A + R_B + R_B)C = 0.69(R_A + 2R_B)C$$

Frequency,

$$f = \frac{1}{T} = \frac{1}{0.69(R_A + 2R_B)C} = \frac{1.45}{(R_A + 2R_B)C}$$

Duty Cycle,

$$\%D = \frac{t_{HIGH}}{T}\, X100 = \frac{0.69(R_A + R_B)C}{0.69(R_A + 2R_B)C}\, X100 = \frac{(R_A + R_B)}{(R_A + 2R_B)}\, X100$$

<u>Problem:</u>

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.

Solution:

t_1 – capacitor charge "ON" time is calculated as:

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

t_2 – capacitor discharge "OFF" time is calculated as:

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

Total periodic time (T) is therefore calculated as:

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

The output frequency, f is therefore given as:

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

Giving a duty cycle value of:

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