**555 Timer:**

The 555 timer is a highly stable controller capable of producing accurate time delays or oscillations. Additional ****, 2 provided for triggering or resetting if desired. In the time – delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For stable operation as an oscillator the free – running frequency and duty cycle are both accurately controlled with two external resistors and one capacitor. The output structure can source or sink up to 200mA or drive TTL circuits.

The following is a block diagram of the timer.

![555 Timer Diagram](image)

555 Timer

(FIG - 1)

**Pin – 1** Ground. The voltage should be the most negative of any voltage appearing at the other pins.

**Pin – 2** Trigger. Level-sensitive point to \( \frac{1}{3} V_{CC} \). When the voltage at this pin is brought below \( \frac{1}{3} V_{CC} \) the flip-flop is set causing pin 3 to produce a high state. Allowable applied voltage is between \( V_{CC} \) and ground.

**Pin – 3** Output. The level here is normally low and goes high during the timing interval. Since the output state is active in both directions, it can source or sink up to 200ma.

**Pin – 4** Reset. When the voltage at this pin is less than 0.4 volts, the timing cycle is interrupted, returning the timer to its non-triggered state. This is an overriding function so that the timer can not be triggered unless reset is released (Pin – 4 > 1.0 volts). Other useful functions include oscillating in the astable mode and state assurance for power-supply start up. Allowable applied voltage is between ground and \( V_{CC} \). When not used, connect to \( V_{CC} \).
Pin – 5  Control voltage. This is an internally derived $\frac{2}{3}V_{cc}$ point. A resistor-to-ground or an external voltage may be connected to pin – 5 to change the comparator reference points. When not used for this purpose, a capacitor-to-ground greater than or equal to 0.01µF is recommended for all applications. The purpose is to filter power-supply noise spikes from causing inconsistent timing. Allowable applied voltage is between ground and $V_{cc}$.

Pin – 6  Threshold. Level sensitive point to $\frac{2}{3}V_{cc}$. When the voltage at this pin is brought greater than $\frac{2}{3}V_{cc}$ the flip-flop is reset causing pin – 3 to produce a low state. Allowable applied voltage is between ground and $V_{cc}$.

Pin – 7  Discharge. The collector of a transistor switch to ground, (pin – 1) It is normally used to discharge the timing capacitor. Since the collector current is limited, it can accommodate very large capacitors (in excess of 1,000µF) without damage.

Pin – 8  $V_{cc}$ power-supply voltage connected here can range from 4.5v to *** with respect to ground (Pin – 1). Timing is relatively independent of this voltage. The timing error due to power-supply variation is typically less than 0.05%/V.

**Astable Multivibrator:**

![Astable Multivibrator Diagram](FIG - 2)

The astable multivibrator in Fig – 2, the operation may be described as follows. The capacitor C starts charging up toward the voltage $V_{cc}$, but when it reaches $\frac{2}{3}V_{cc}$, the threshold, Pin – 6, switches comparator I which resets the flip-flop. This means $\overline{Q}$ is high and the discharge transistor, Pin – 7, turns on allowing the capacitor C to discharge through $R_B$ to ground (transistors collector to emitter). When the capacitors voltage reaches $\frac{1}{3}V_{cc}$, the triggers, Pin – 2, switches comparator II which in turn sets the flip-flop. This will cause the discharge transistor to shut-off since its base goes low because $\overline{Q}$ is low. This then ends the cycle. Now the capacitor C will start charging up again through $R_A + R_B$ to start a new cycle. The output is the inversion of the flip-flop output $\overline{Q}$.

The charge time (output high) can be calculated from the results of the following derivation, looking at Fig – 2 and te capacitor voltage waveform to its right, we find the following equation to be a solution to the voltage function for the time $t$,
At \( t = 0 \), the capacitor voltage is \( \frac{1}{3} V_{CC} \). Hence,

\[
\frac{V_{CC}}{3} = K_1 - K_2
\]

At \( t = \infty \), the capacitor voltage is \( V_{CC} \). Hence,

\[
V_{CC} = K_1
\]

Substituting this result into the above we may solve for \( K_2 \).

\[
\frac{V_{CC}}{3} = V_{CC} - K_2
\]

\[
K_2 = \frac{2V_{CC}}{3}
\]

Therefore,

\[
V_C = V_{CC} - \frac{2}{3} V_{CC} e^{-\frac{t}{R_T C}}
\]

Now solving the above equation for the time \( t \), when \( t = t_1, V_C = \frac{2}{3} V_{CC} \).

\[
\frac{2}{3} V_{CC} = V_{CC} - \frac{2}{3} V_{CC} e^{-\frac{t_1}{R_T C}} \rightarrow \frac{1}{3} V_{CC} = -\frac{2}{3} V_{CC} e^{-\frac{t_1}{R_T C}}
\]

\[
\frac{1}{2} = e^{-\frac{t_1}{R_T C}} \rightarrow 2 = e^{\frac{t_1}{R_T C}}
\]

\[
t_1 = R_T C \ln 2 = 0.693 R_T C
\]

\[
t_1 = 0.693(R_A + R_B)C
\]

The solution for the discharge time maybe found from the following general equation.

\[
V_C = K_3 e^{-\frac{t}{R_{BC}}} 
\]

When, \( t = 0, V_{CC} = \frac{2}{3} V_{CC} \) and \( t = \infty, V_C = 0. \) Hence,

\[
V_C = \frac{2}{3} V_{CC} e^{-\frac{t}{R_{BC}}}
\]

Solving the above for the time \( t_2 \). We note, when \( t = t_2, V_C = \frac{V_{CC}}{3} \). Hence,

\[
\frac{1}{3} V_{CC} = \frac{2}{3} V_{CC} e^{-\frac{t_2}{R_{BC}}}
\]

\[
\frac{1}{2} = e^{-\frac{t_2}{R_{BC}}}
\]

\[
t_2 = R_B C \ln 2 = R_B C(0.693)
\]
The total period is then,

\[ T = t_1 + t_2 = 0.693(R_A + R_B)C + 0.693R_B C \]

And the frequency of oscillation would be,

\[ f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)C} \]

The duty cycle can then be defined as,

\[ D = \frac{R_A + R_B}{R_A + 2R_B} \quad \text{(Duty Cycle > 50\%)} \]

If a diode is connected between points A and B as shown below, such that it is in parallel with \( R_B \), the equations for this change can be expressed as follows. This will allow a duty cycle less than 50%.

\[ t_1 \approx 0.693R_A C \quad (V_D \approx 0) \quad V_{out} \text{ high} \]

And,

\[ t_2 \approx 0.693R_B C \quad (V_D \approx 0, \text{open in this direction}) \quad V_{out} \text{ low} \]

\[ f \approx \frac{1.44}{(R_A + R_B)C} \]

\[ D \approx \frac{R_A}{R_A + R_B} \]

If Pin – 4, the reset control, is grounded it will stop the oscillations, thus the possibility exists to form a gated oscillator if Pin – 4 is controlled externally.

The minimum value of \( R_A \) is established from the fact that the initial charging current I must not be so large as to prevent the discharge transistor from doing its job. Initial charging should be limited to 5ma. The maximum value of \( R_A \) is determined by the threshold current required at Pin – 6. Initial minimum charging current is 1µA. For any power-supply voltage, then, the timing can be verified by 500 to 1 by charging only \( R_A \).
Equation for One – Shot:

\[ V_C = K_1 - K_2 e^{-\frac{t}{R_A C}} \quad \text{General equation.} \]

@ \( t = 0 \) \quad 0 = K_1 - K_2

@ \( t = \infty \) \quad K_1 = V_{CC} = K_2

Hence,

\[ V_C = V_{CC} - V_{CC} e^{-\frac{t}{R_A C}} \]

Find \( t \) at \( V_C = \frac{2}{3} V_{CC} \) (Time when one-shot fires).

\[ \frac{2}{3} V_{CC} = V_{CC} - V_{CC} e^{-\frac{t}{R_A C}} \]

\[ \frac{2}{3} = 1 - e^{-\frac{t}{R_A C}} \]

\[ -\frac{1}{3} = -e^{-\frac{t}{R_A C}} \]

\[ t = \ln 3 \cdot R_A C \]

\[ t = 1.1 R_A C \]