

555 Timer

CM

Introduction

- → name **555 timer** comes from the fact that there are three internally connected 5kΩ resistors which it uses to generate the two comparators reference voltages.
- very cheap, popular and useful precision timing device
- can be used either as a simple timer to generate single pulses or long time delays or as a relaxation oscillator producing a string of stabilised waveforms of varying duty cycles from 50 to 100%.

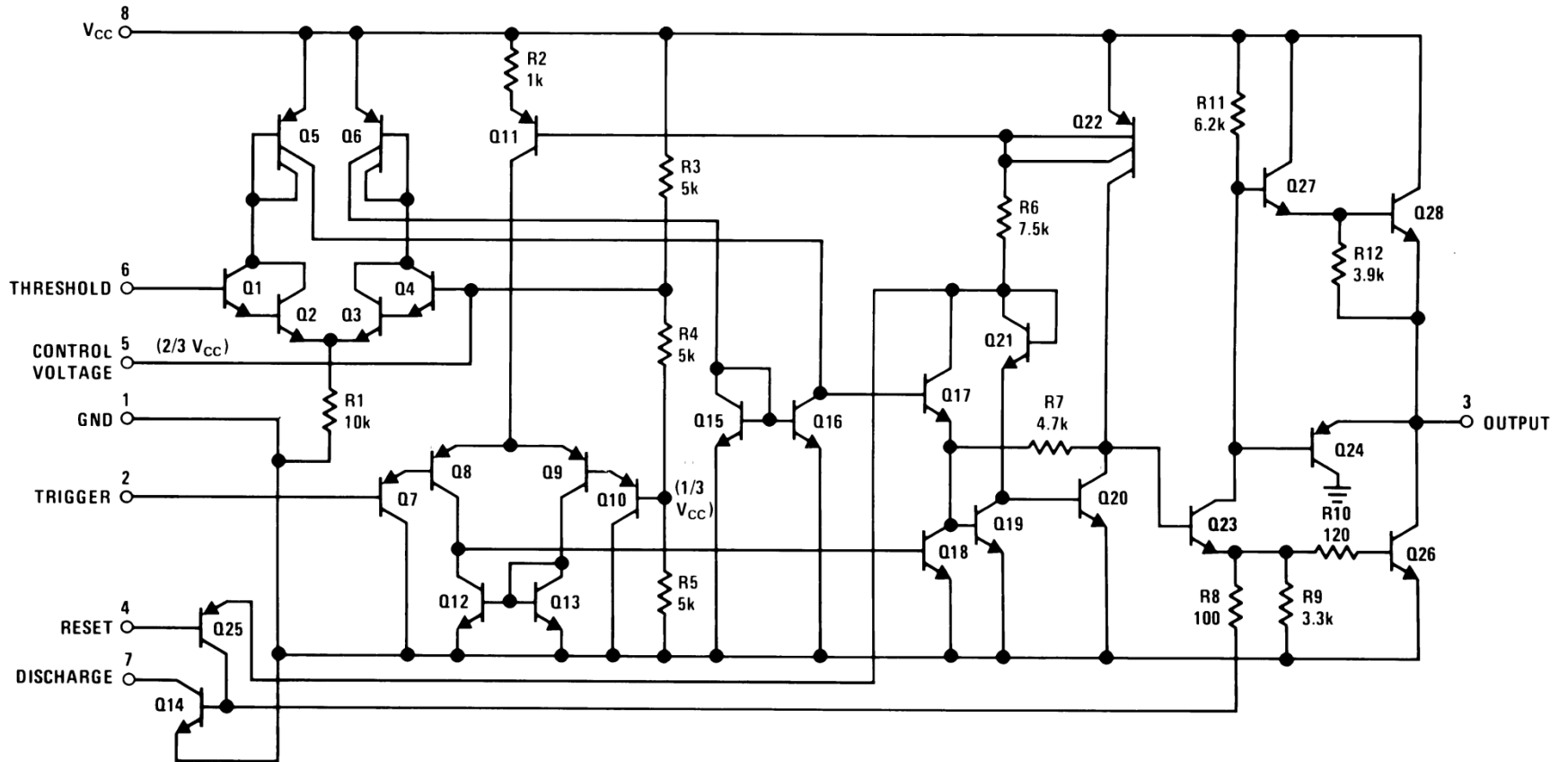
Description

- The LM555 is a highly stable device for generating accurate time delays or oscillation.
- Additional terminals are 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 a stable operation as an oscillator,
- the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor.
- The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 mA or drive TTL circuits

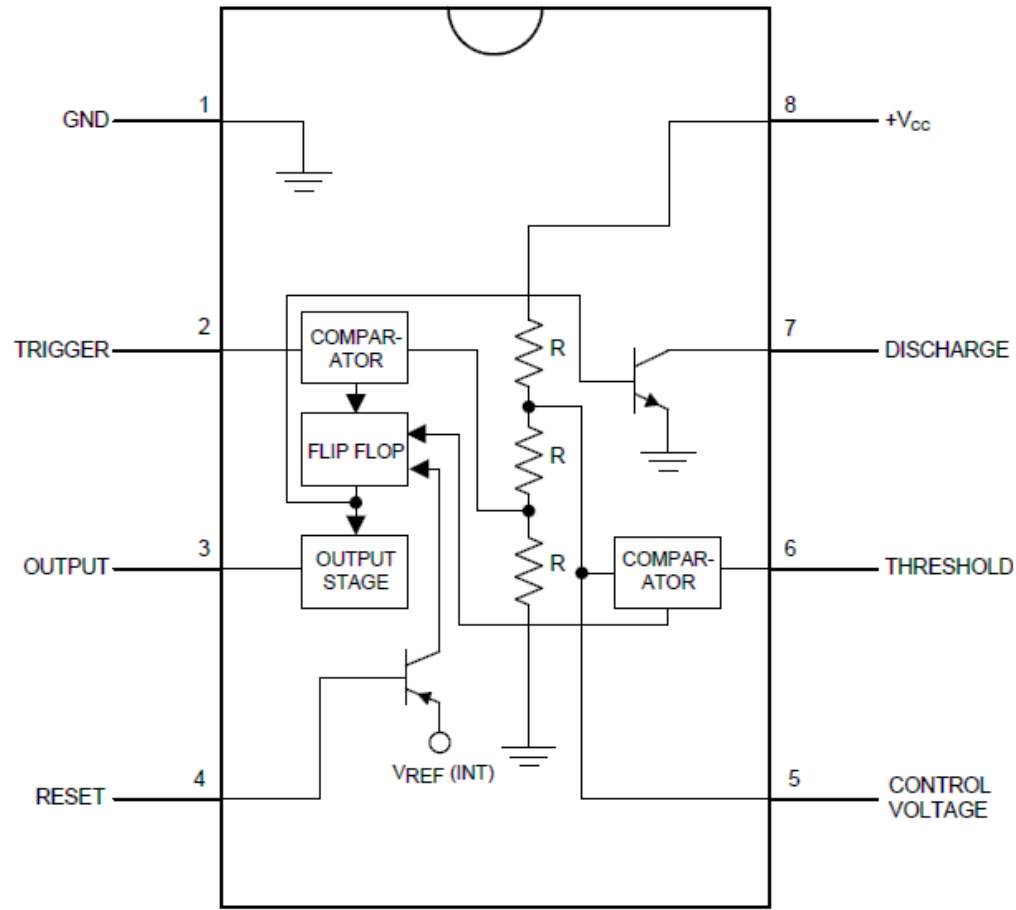
Features

- 1. Timing from Microseconds through Hours .
- 2. Operates in Both Astable and Monostable Modes
- 3. Adjustable Duty Cycle
- 4. Output Can Source or Sink 200 mA
- 5. Output and Supply TTL Compatible
- 6 Temperature Stability Better

LM555



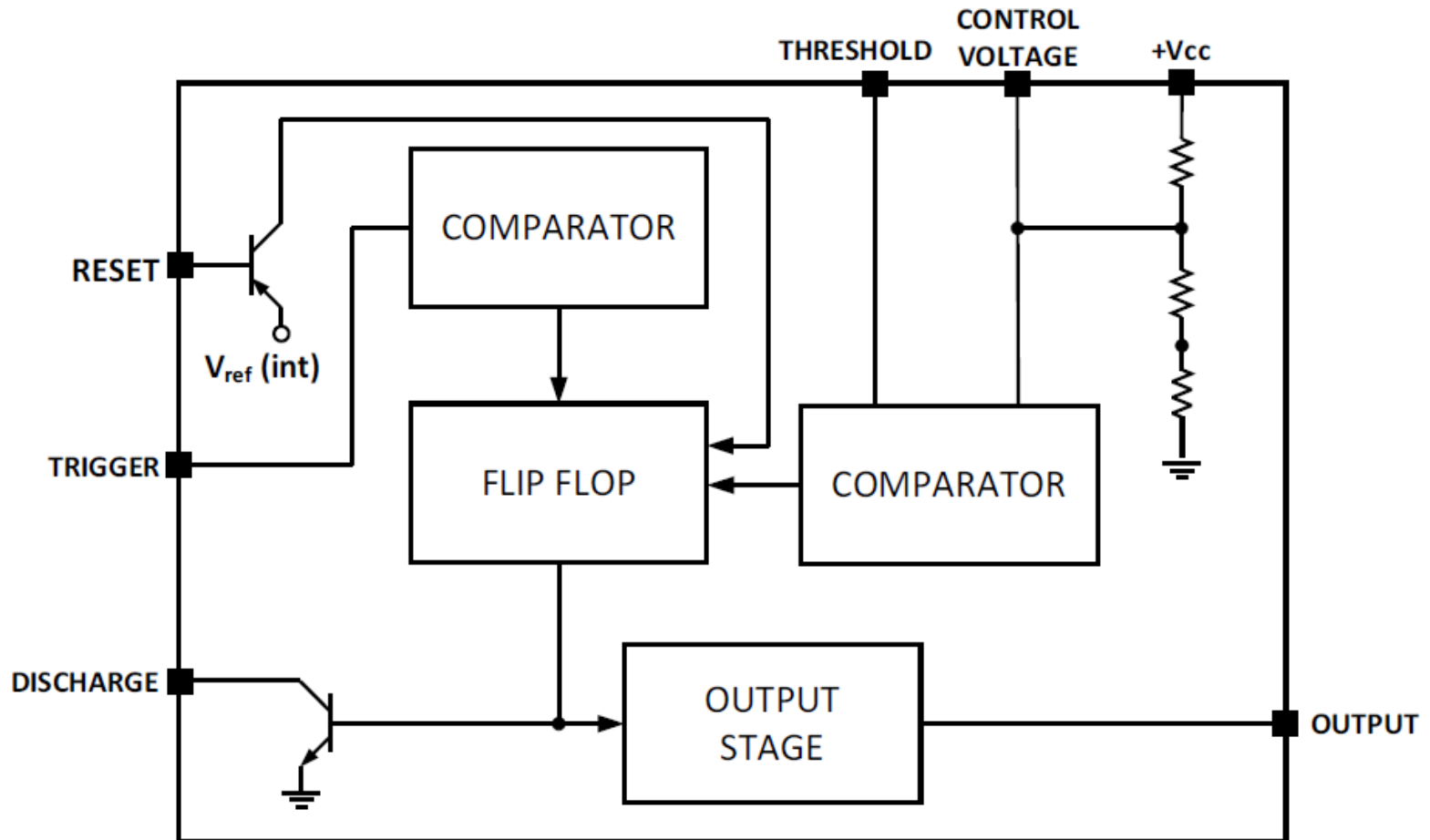
Pin Configuration

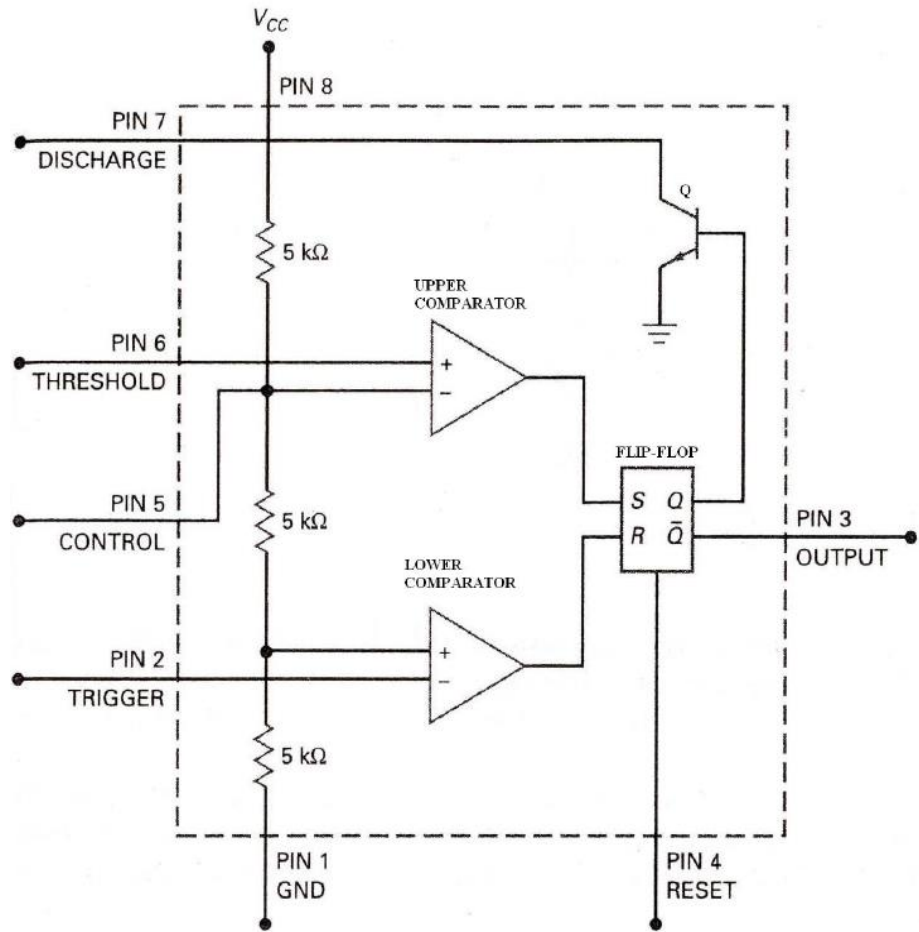
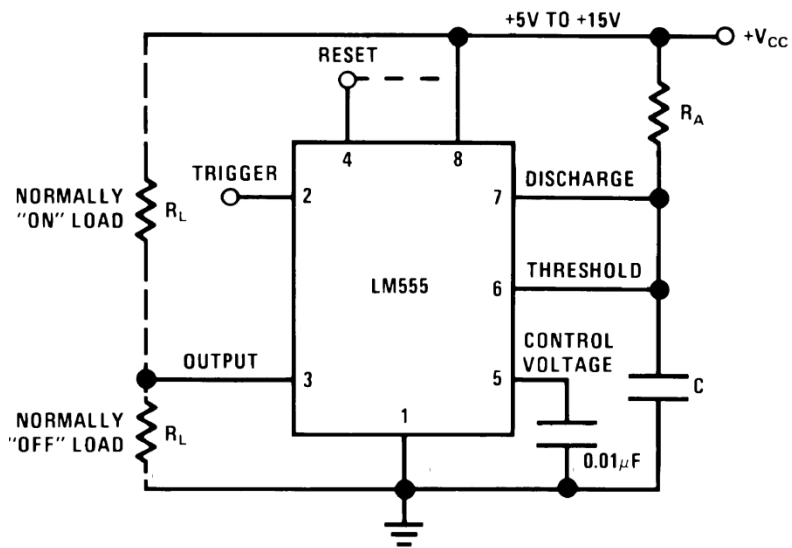


Functions

| Pin | | I/ O | Function |
|-----|-----------------|---------|---|
| No. | Name | | |
| 1 | Gnd | I | Ground reference voltage |
| 2 | Trigger | I | Responsible for transition of the flip-flop from set to reset. The output of the timer depends on the amplitude of the external trigger pulse applied to this pin |
| 3 | output | O | Output driven waveform |
| 4 | Reset | I | Negative pulse applied to this pin to disable or reset the timer. When not used for reset purposes, it should be connected to supply voltage to avoid false triggering |
| 5 | Control voltage | I | Controls the threshold and trigger levels. It determines the pulse width of the output Voltage waveform. An external voltage applied to this pin can also be used to modulate the output waveform |
| 6 | threshold | I | Compares the voltage applied to the terminal with a reference voltage of $2/3 V_{cc}$. The amplitude of voltage applied to this terminal is responsible for the set state of the flip-flop |
| 7 | Discharge | I | Open collector output which discharges a capacitor between intervals (in phase with output). It toggles the output from high to low when voltage reaches $2/3$ of the supply voltage |
| 8 | V ⁺ | I | Supply voltage wrt ground |

Functional block diagram

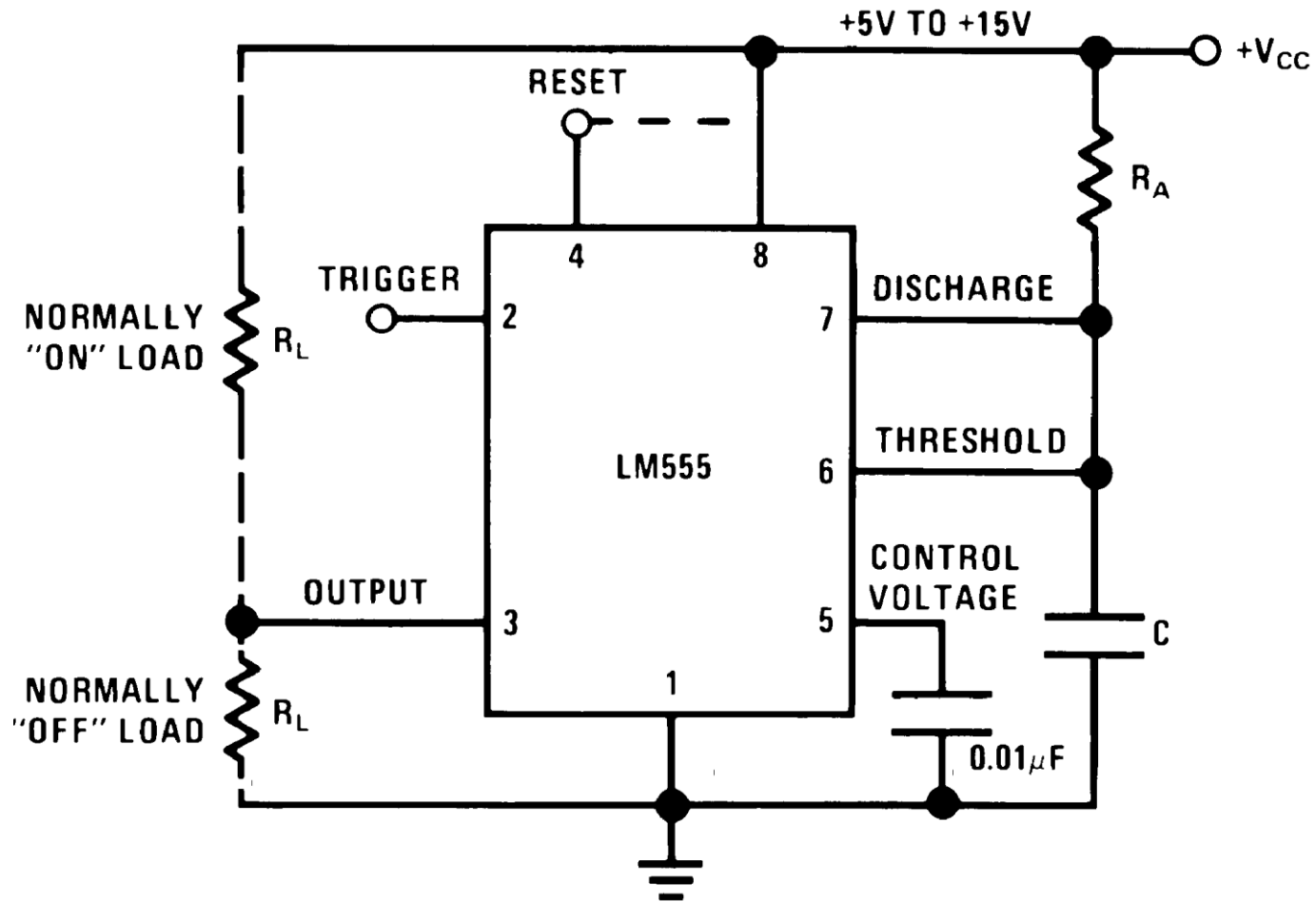




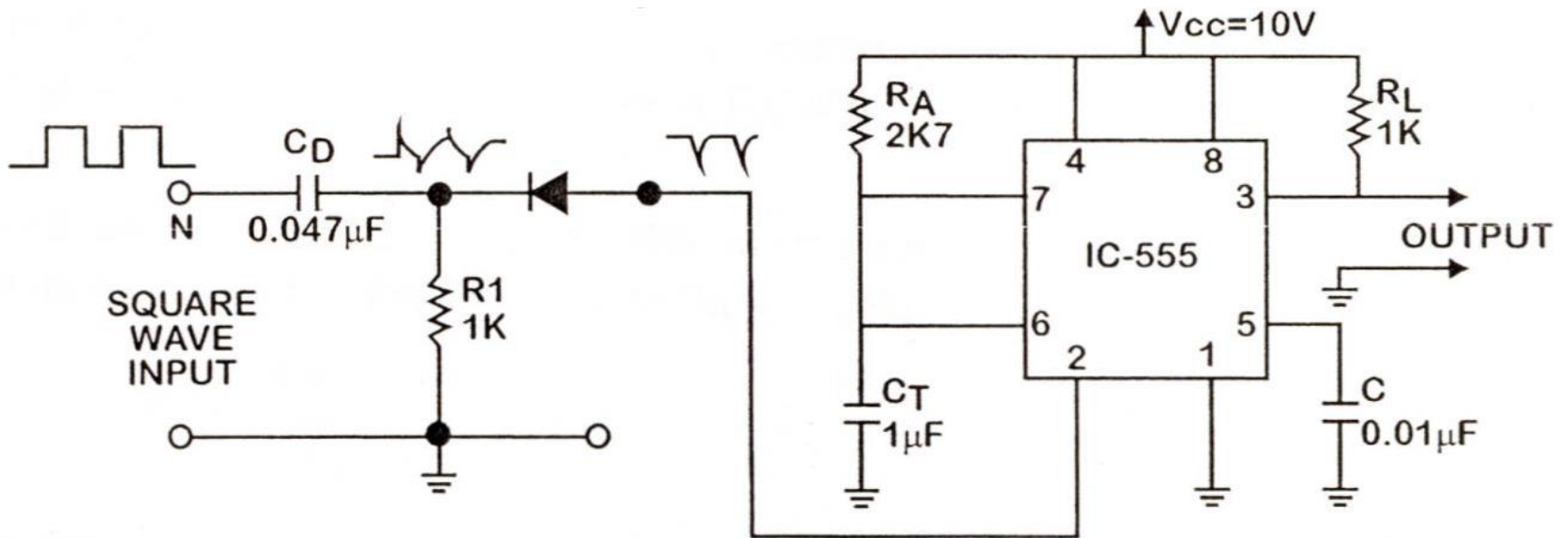
Mode of operation

- LM555 can operate in both astable and monostable mode depending on the application requirements.

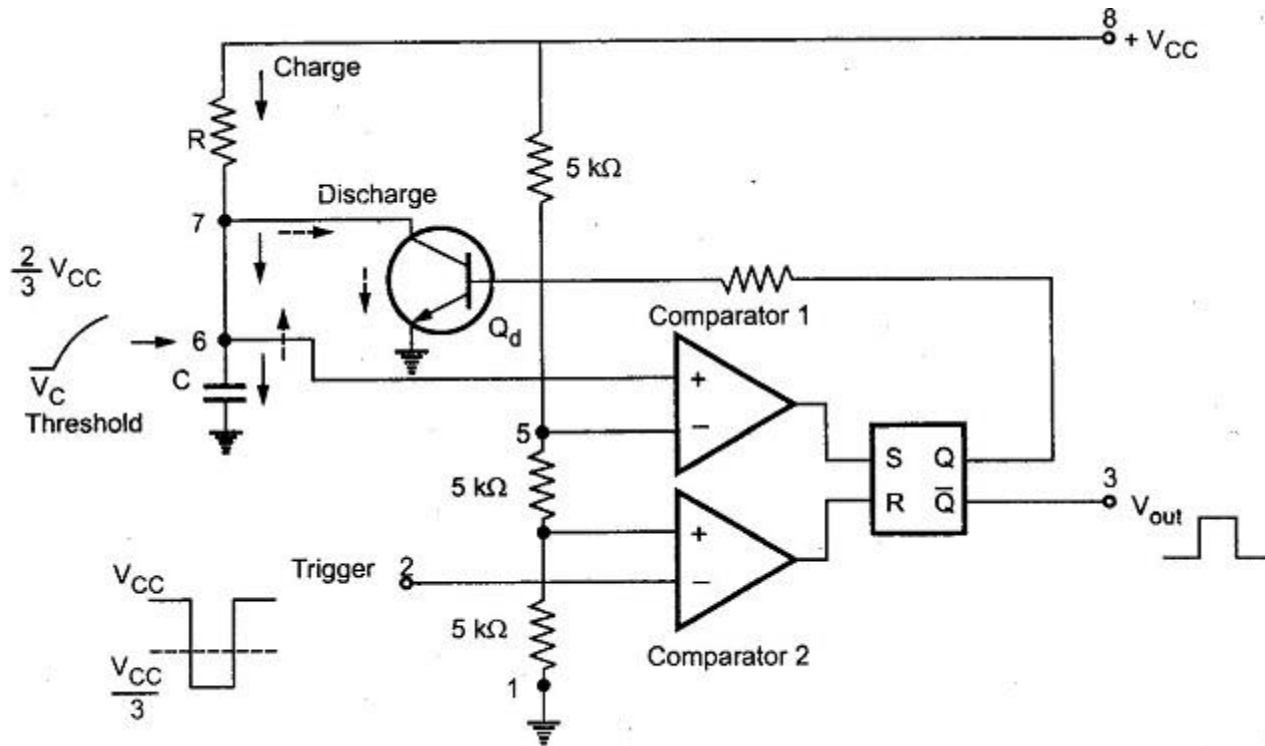
Monostable Operation



Monostable



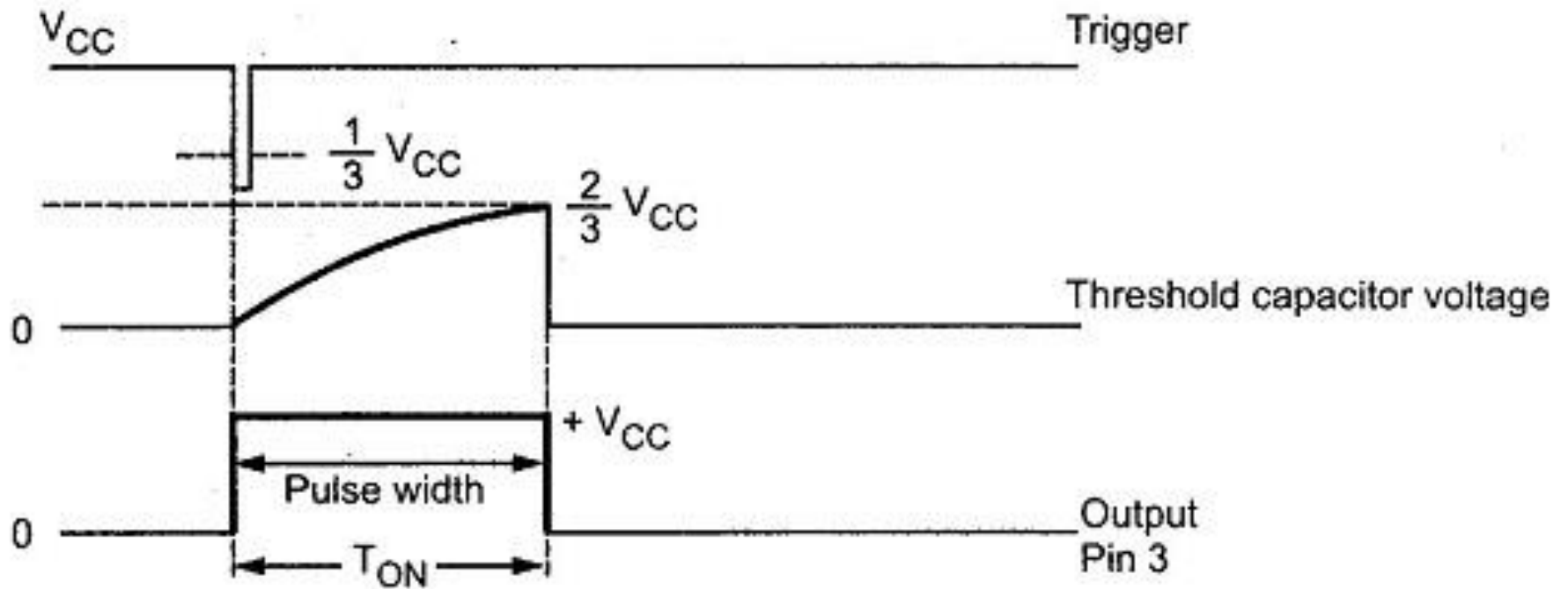
MSMV



Operation

- The flip-flop is initially set i.e. Q is high. This drives the transistor Q_d in saturation. The capacitor discharges completely and voltage across it is nearly zero. the output at pin 3 is low.
- When a trigger input, a low going pulse is applied, then circuit state remains unchanged till trigger voltage is greater than $1/3 V_{cc}$. When it becomes less than $1/3 V_{cc}$, then comparator 2 output goes high. This resets the flip-flop so \bar{Q} goes low and Q goes high. Low Q makes the transistor Q_d off. Hence capacitor starts charging through resistance R
- The voltage across capacitor increases exponentially. This voltage is nothing but the threshold voltage at pin 6. When this voltage becomes more than $2/3 V_{cc}$, then comparator 1 output goes high. This sets the flip-flop i.e. Q becomes high and low. This high Q drives the transistor Q_d in saturation. Thus capacitor C quickly discharges through Q_d as shown by dotted arrows in the Fig

Waveforms



Pulse width

$$V_C = V (1 - e^{-t/CR})$$

If

$$V_C = \frac{2}{3} V_{CC}$$

then

$$\frac{2}{3} V_{CC} = V_{CC} (1 - e^{-t/CR})$$

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

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

$$-\frac{t}{CR} = -1.0986$$

$$t = +1.0986 CR$$

$$t \approx 1.1 CR$$

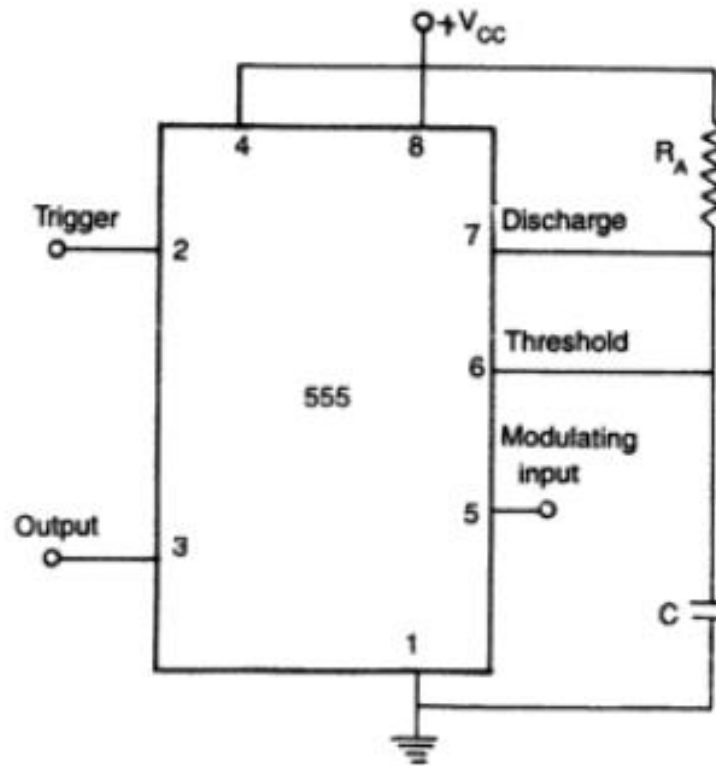
$$V_C = kV_{CC}$$

$$RC \ln(1/(1 - V_C/V_{CC})) = t$$

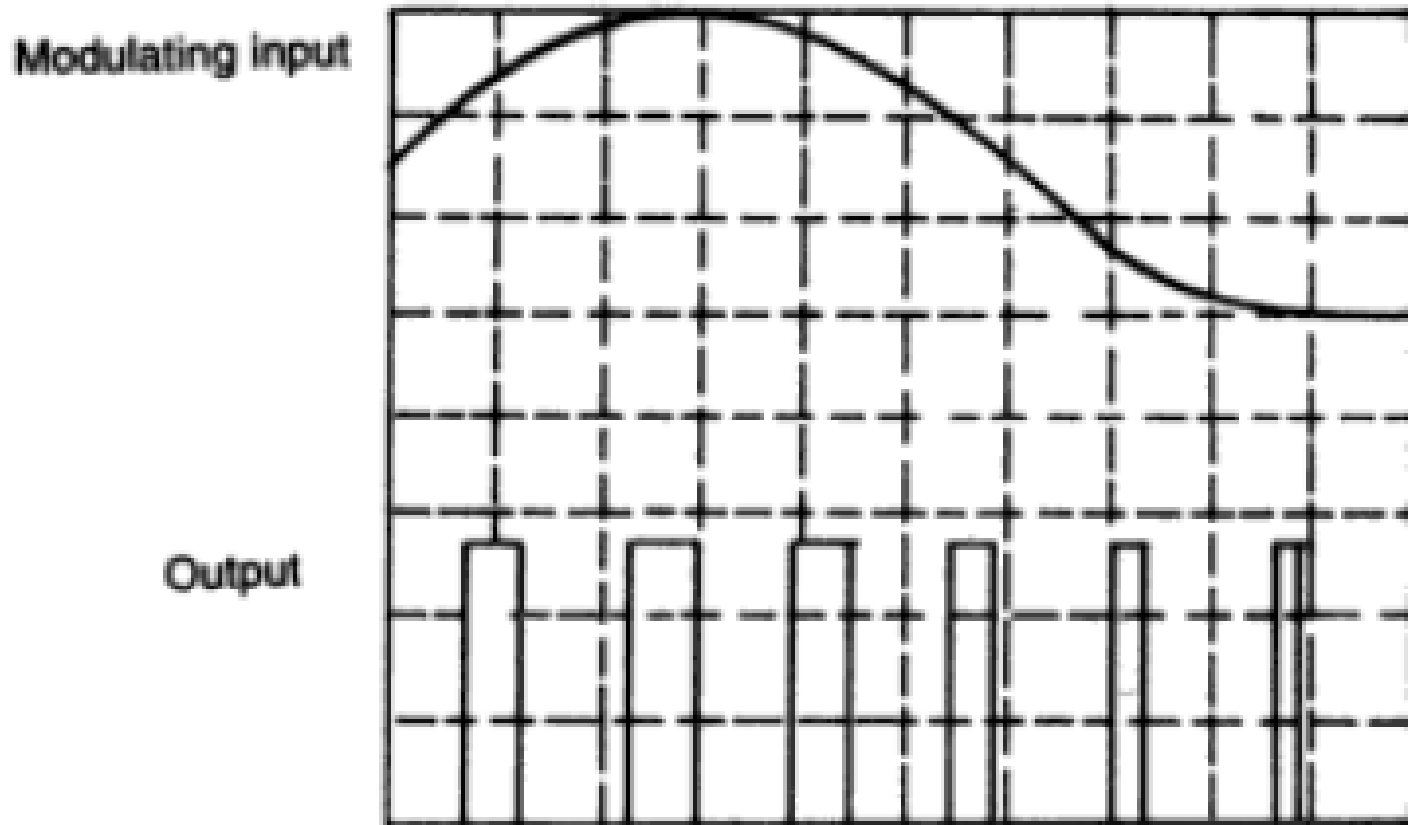
Applications:

- The various applications of monostable circuit are,
- Frequency divider
- Pulse width modulation
- Linear ramp generator
- Pulse position modulation
- Missing pulse detector
- Timer in relay

Pulse Width Modulation



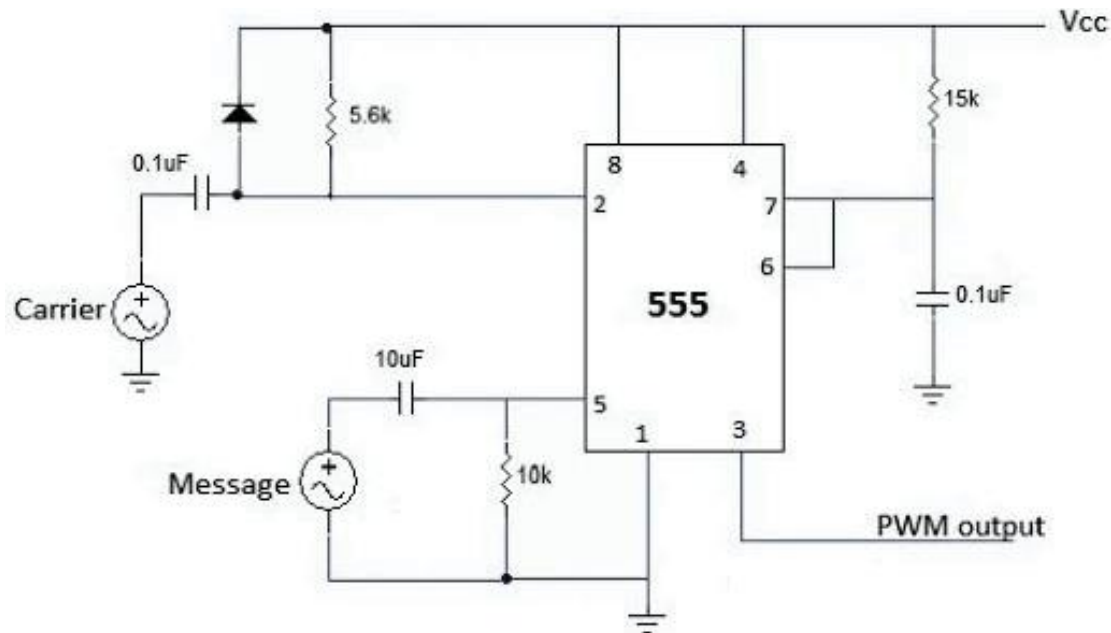
Waveforms



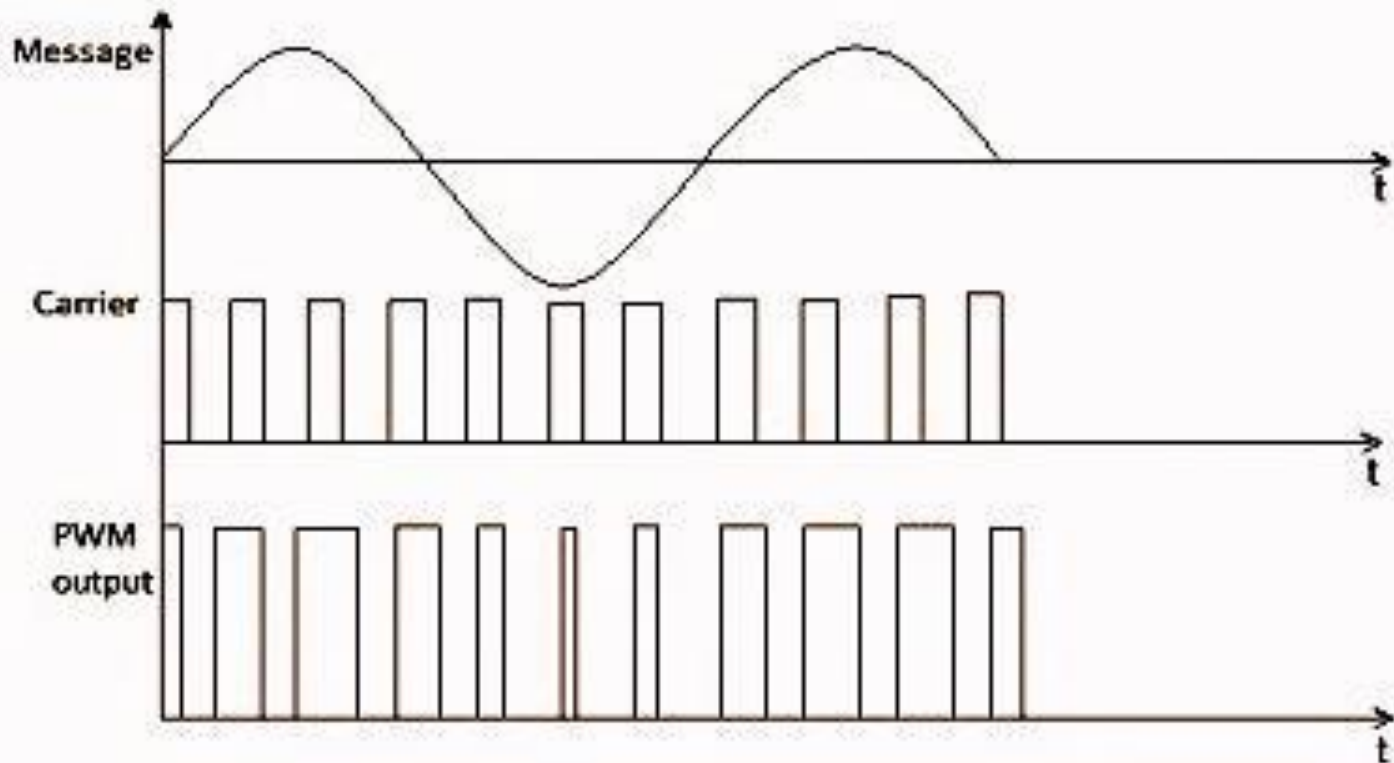
- In this mode the output is LOW (0V) when there is no triggering
- when it is triggered via pin 2 the output goes HIGH (V_{cc}) for some time. This time period is determined by the expression $T = 1.1 R_A C$
- And now this output is modulated using the input voltage applied at the control pin 5 of the IC.
- So whenever the trigger pin pulses become low, the output of the IC switches to high and as a result the discharge transistor (see internal ckt of the 555 IC) is disabled.
- So C charges through R.
- This capacitor keeps on charging until the voltage is above the input control voltage, at which the IC changes its state.
- Now the output is low which makes the discharge transistor activated thereby discharging the capacitor C.
- Hence the output pulse width is determined by the control voltage. This process continues and we get a continuous stream of pulses which can be used for motor control, driving LED's, transmitting servo signals for remote control applications etc.
- Pulse width varies i.e., duty cycle varies but the frequency remains constant.

Triggering

- Trigger is applied via a differentiator circuit to make sharp pulses. The resistor of differentiator is connected to V_{cc} to generate negative trigger pulses and the diode avoids positive spikes.

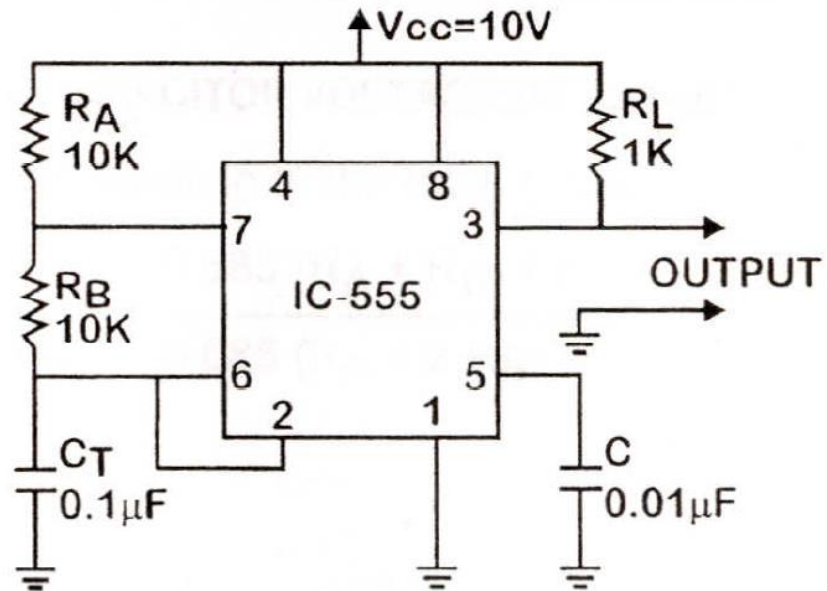


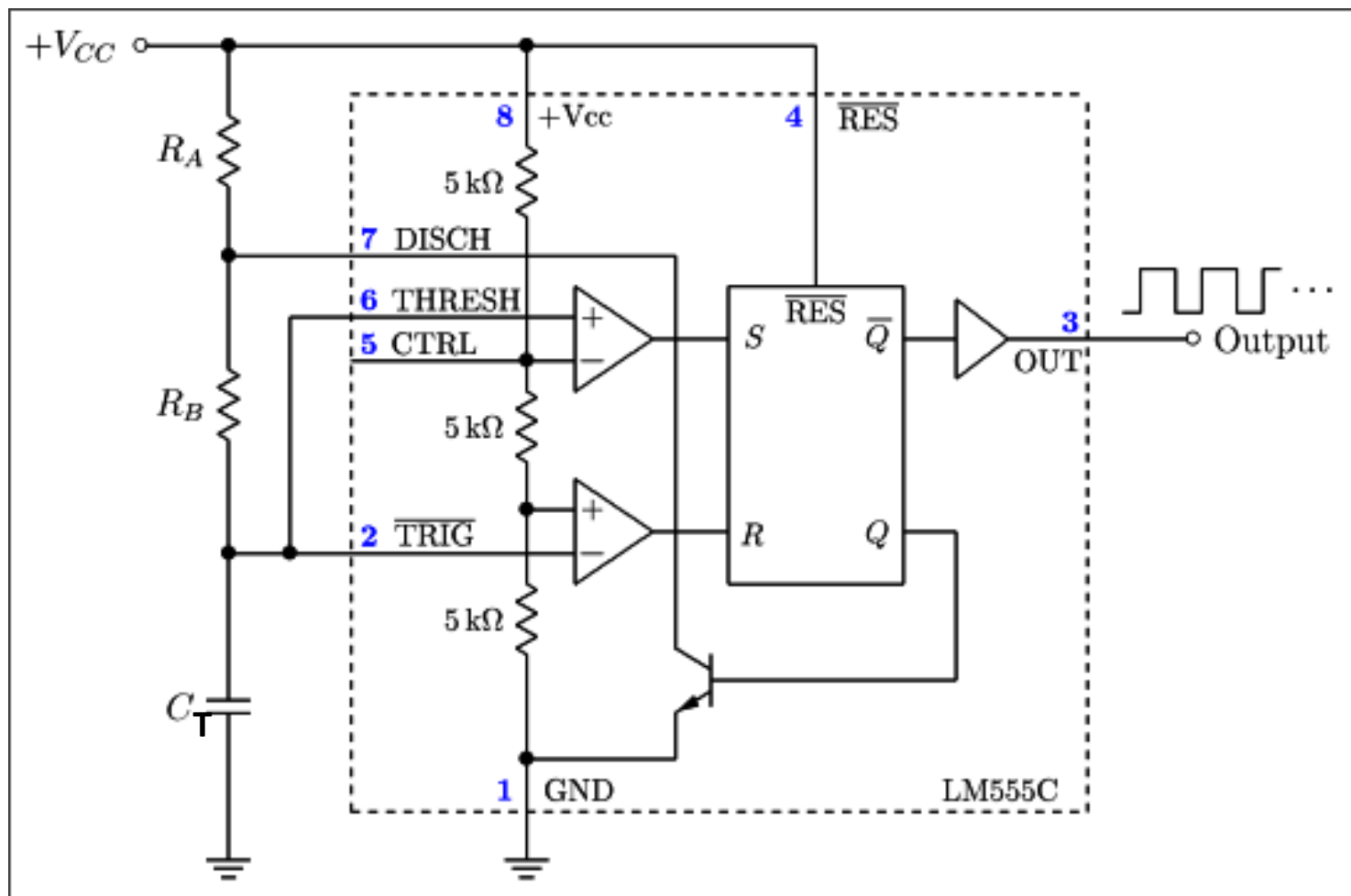
waveforms



Astable Multivibrator

The most common use of IC 555 is to provide pulses at regular intervals, i.e., act as a clock. This can be achieved by using external resistors (R_A and R_B) and one capacitor (C_T) with IC 555. The time period and duty cycle of the clock cycle depends on the values of resistors and capacitor used.





Operation

- The astable function is achieved by charging/discharging a capacitor through resistors connected, respectively, either to VCC or GND.
- Switching between the charging and discharging modes is handled by resistor divider R1-R3, two Comparators, and an RS Flip-Flop in IC 555. The upper or lower comparator simply generates a positive pulse if VC goes above $2/3$ VCC or below $1/3$ VCC. And these positive pulses either SET or RESET the Q output.
- The time for charging C from $1/3$ to $2/3$ Vcc,
 - **ON Time = $0.693 (R_A + R_B) \cdot C_T$**
- The time for discharging C from $2/3$ to $1/3$ Vcc,
 - **OFF Time = $0.693 R_B \cdot C_T$**
- To get the total oscillation period, just add the two:
 - **Tosc = $0.693(R_A+R_B)C_T + 0.693(R_B)C_T = 0.693 (R_A + 2R_B) \cdot C_T$**

Astable Multivibrator using 555 – Design Theory

- The time during which the capacitor C charges from $1/3 V_{CC}$ to $2/3 V_{CC}$ is equal to the time the output is high and is given as T_{HIGH}

- Voltage across the capacitor at any instant during charging period is given as, $v_c = V_{CC}(1 - e^{-t/RC})$

- The time taken by the capacitor to charge from 0 to $+1/3 V_{CC}$

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$$t_1 = 1/3 V_{CC} = V_{CC} (1 - e^{-t/RC})$$

- The time taken by the capacitor to charge from 0 to $+2/3 V_{CC}$

$$t_2 = RC \log_e 3 = 1.0986 RC$$

- So the time taken by the capacitor to charge from $+1/3 V_{CC}$ to $+2/3 V_{CC}$

$$T_{High} = (t_2 - t_1) = (1.0986 - 0.405) RC = 0.693 RC$$

- Substituting $R = (R_A + R_B)$ and $C = C_T$ in above equation we have

$$T_{HIGH} = 0.693 (R_A + R_B) C_T$$

- where R_A and R_B are in ohms and C is in farads.

- The time during which the capacitor discharges from $+2/3 V_{CC}$ to $+1/3 V_{CC}$ is equal to the time the output is low and is given as T_{LOW}

- Voltage across the capacitor at any instant during discharging period is given as

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

- Substituting $R = R_B$, $v_c = 1/3 V_{CC}$ and $t = T_{LOW}$ in above equation we have

$$+1/3 V_{CC} = +2/3 V_{CC} e^{-T_{LOW}/R_B C_T}$$

$$T_{LOW} = 0.693 R_B C_T$$

Design Theory

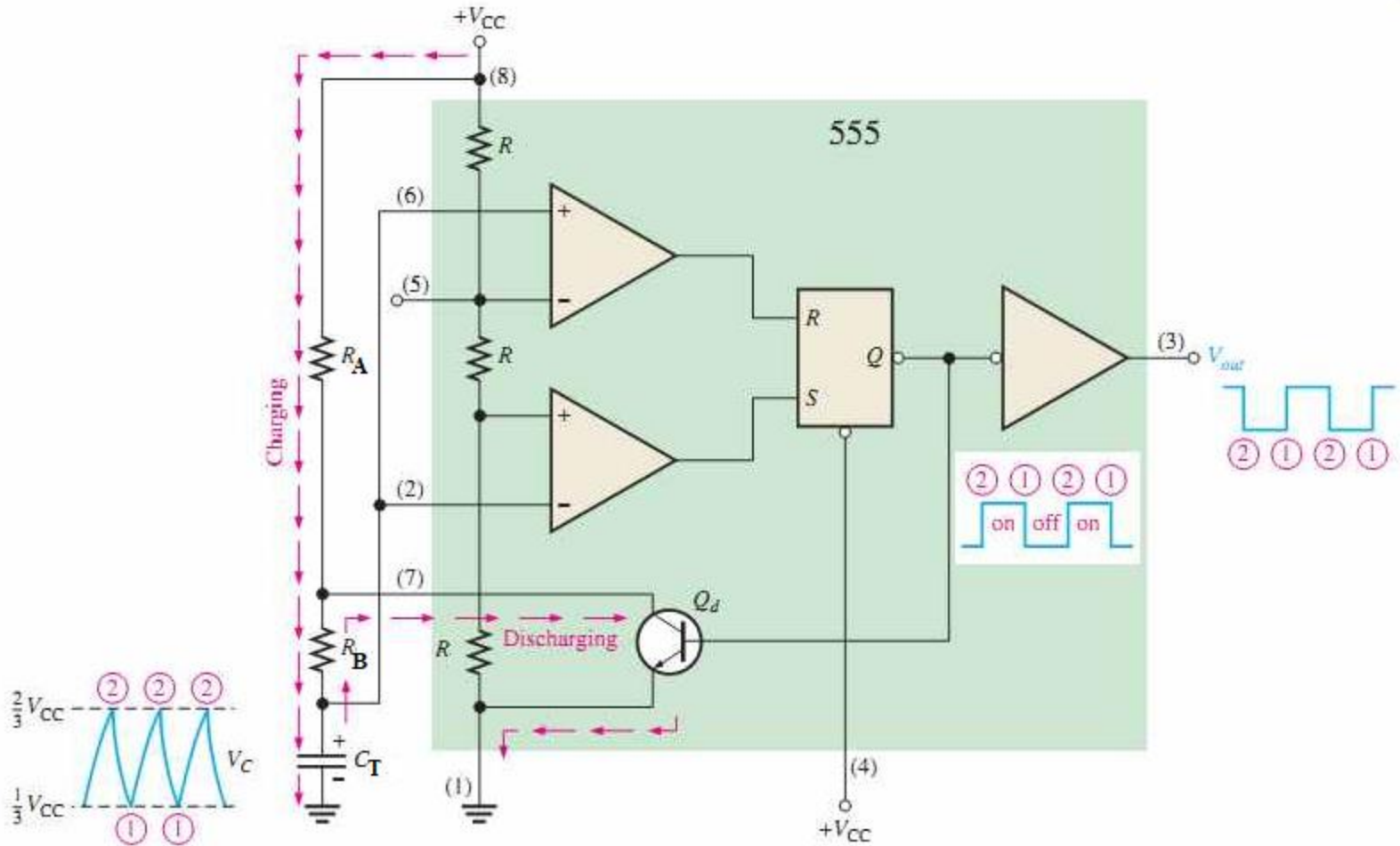
- Or Overall period of oscillations,
$$T = T_{\text{HIGH}} + T_{\text{LOW}} = 0.693 (R_A + 2R_B) C_T$$
- The frequency of oscillations being the reciprocal of the overall period of oscillations T is given as
$$f_{\text{osc}} = 1/T = 1.44 / (R_A + 2R_B) C_T$$
- Equation indicates that the frequency of oscillation is independent of the collector supply voltage.
- Often the term duty cycle is used in conjunction with the astable multivibrator.

- ***The duty cycle, the ratio of the time during which the output is high to the total time period T is given as***

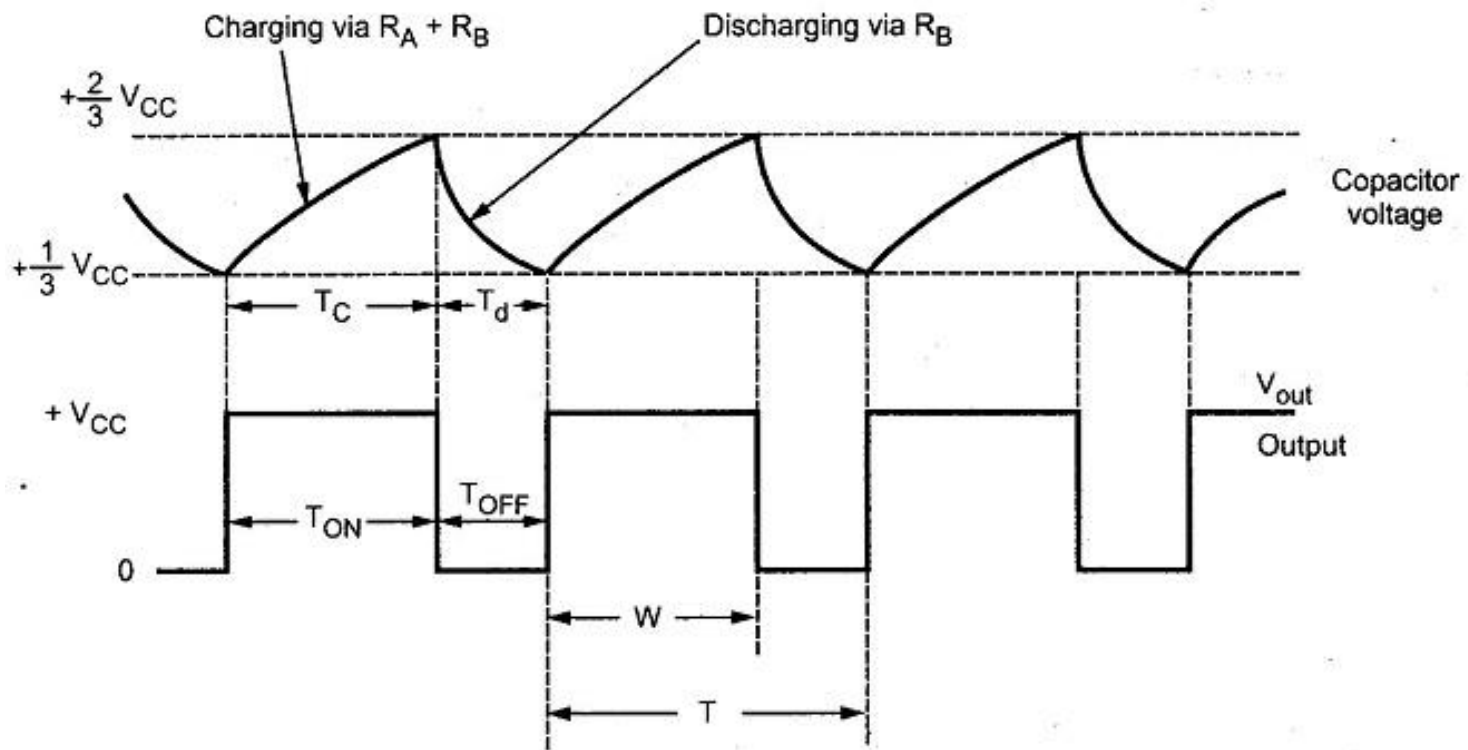
$$\% \text{ duty cycle, } D = T_{\text{HIGH}} / T * 100 \% = (R_A + R_B) / (R_A + 2R_B) * 100\%$$

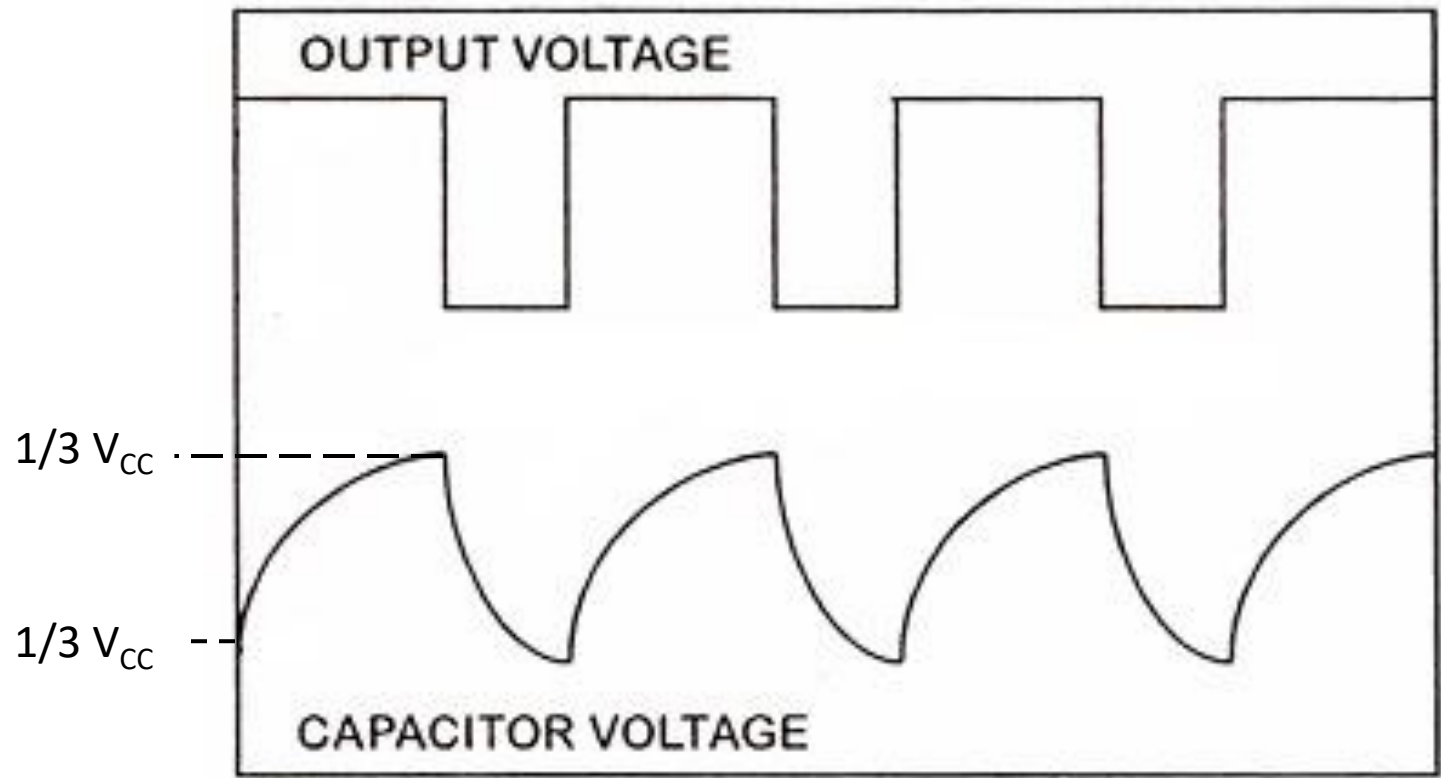
- From the above equation it is obvious that square wave (50 % duty cycle) output
- can not be obtained unless R_A is made zero. However, there is a danger in shorting resistance R_A to zero. With $R_A = 0$ ohm, terminal 7 is directly connected to $+V_{CC}$. During the discharging of capacitor through R_B and transistor, an extra current will be supplied to the transistor from V_{CC} through a short between pin 7 and $+V_{CC}$. It may damage the transistor and hence the timer.
- However, a symmetrical square wave can be obtained if a diode is connected across resistor R_B , as illustrated in dotted lines in figure. The capacitor C charges through R_A and diode D to approximately $+ 2/3V_{CC}$ and discharges through resistor R_B and terminal 7 (transistor) until the capacitor voltage drops to $1/3 V_{CC}$. Then the cycle is repeated. To obtain a square wave output, R_A must be a combination of a fixed resistor R and a pot, so that the pot can be adjusted to give the exact square wave.

ASMV

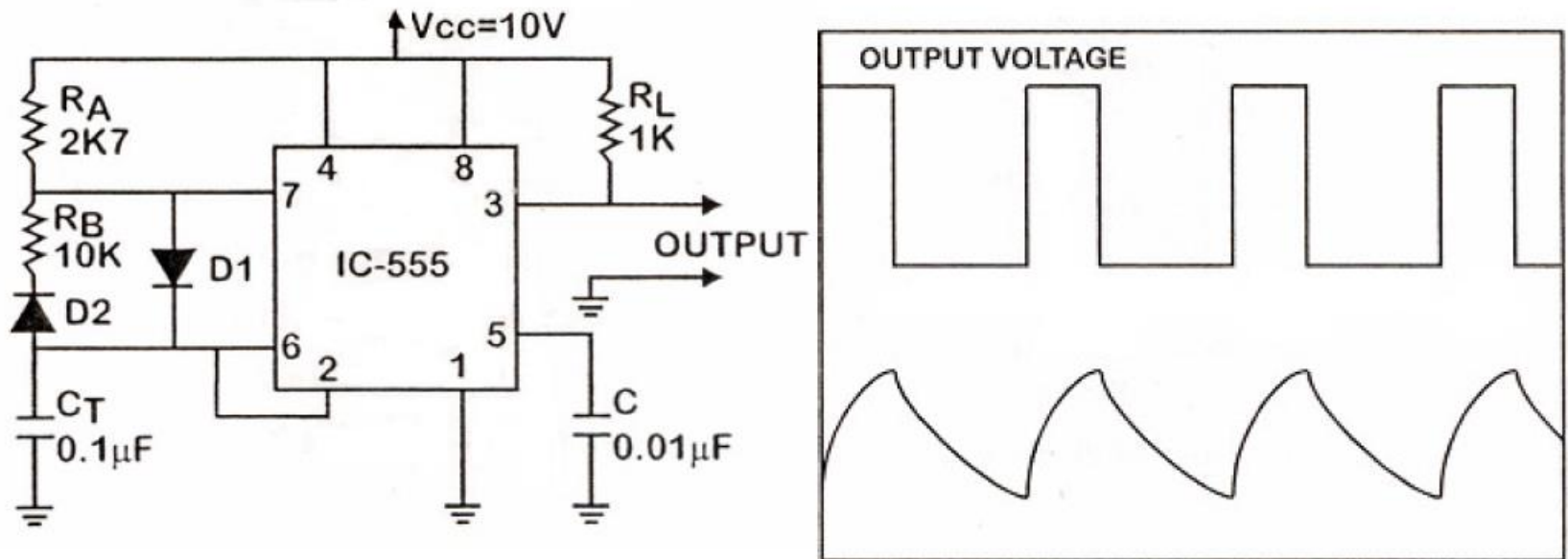


Waveforms





Astable multivibrator with duty cycle variable from 0 to 100%:



C_T charges through R_A only and discharges through R_B

$$T = T_{HIGH} + T_{LOW} = 0.693 (R_A + R_B) C_T$$

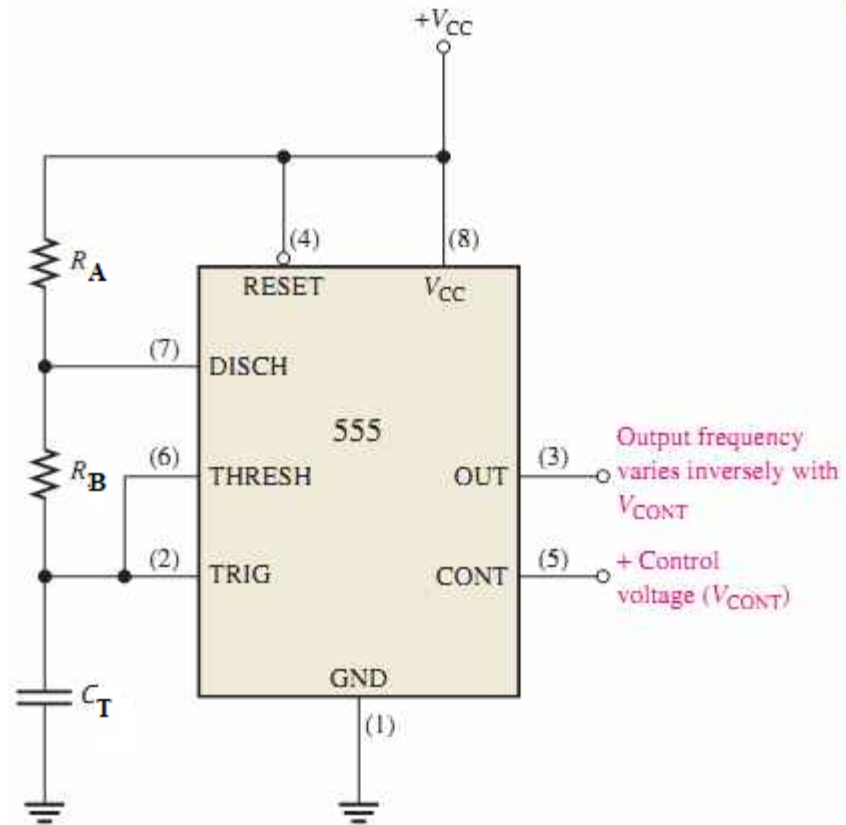
$$\text{Duty cycle } D = R_A / (R_A + R_B)$$

Using a potentiometer as R_B , Duty cycle can be changed

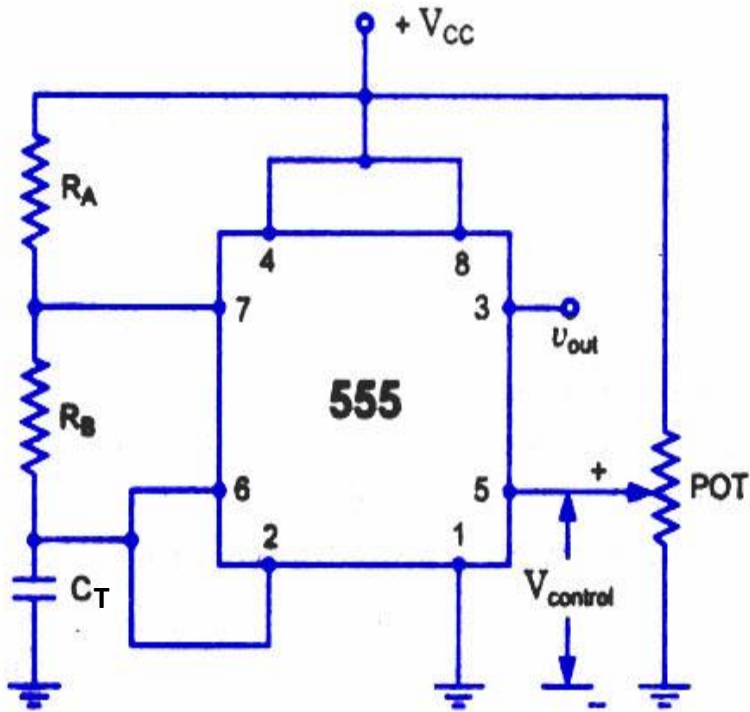
Application of Astable Multivibrator using IC 555:

- The various Application of Astable Multivibrator using IC 555 are,
- **Square wave generation**
- **FSK generator**
- **Voltage controlled oscillator (VCO)**

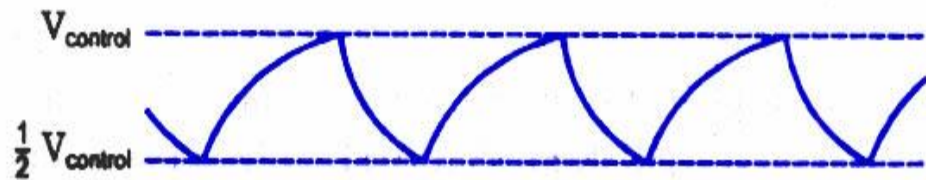
VCO



VCO



Circuit



Timing Capacitor Voltage Waveform

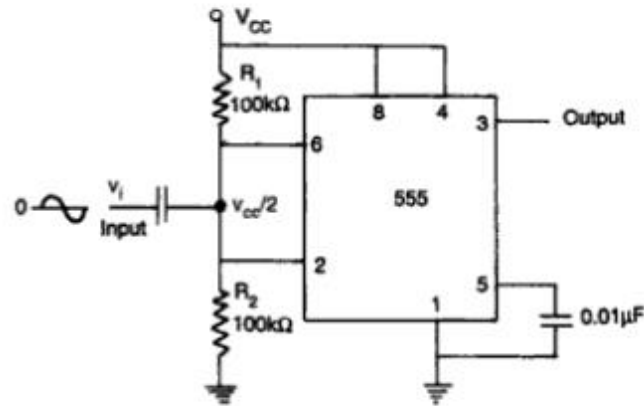
Voltage Controlled Oscillator

Operation

- Normally, the control voltage is $+2/3V_{CC}$ because of the internal voltage divider.
- However, an external voltage can be applied to this terminal directly or through a pot
- by adjusting the pot, control voltage can be varied.
- Voltage across the timing capacitor is depicted in figure, which varies between $+V_{control}$ and $1/2 V_{control}$.
- If control voltage is increased, the capacitor takes a longer to charge and discharge; the frequency, therefore, decreases.
- Thus the frequency can be changed by changing the control voltage. Incidentally, the control voltage may be made available through a pot, or it may be output of a transistor circuit, op-amp, or some other device.

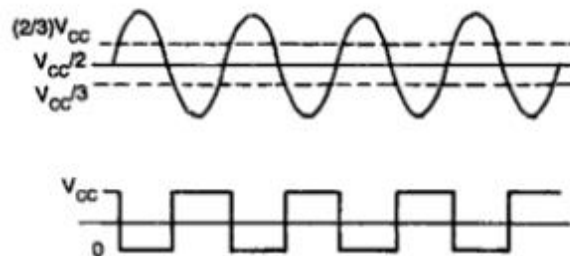
SCHMITT TRIGGER

The use of 555 timer as a Schmitt Trigger is shown in Fig. The two internal comparators are tied together and externally biased at $V_{cc}/2$ through R_1 and R_2 . Since the upper comparator will trip at $(2/3)V_{cc}$ and lower comparator at $(1/3)V_{cc}$, the bias provided by R_1 and R_2 is centered within these two thresholds.



Timer in Schmitt Trigger Operation

Thus, a sine wave of sufficient amplitude ($> V_{cc}/6 = 2/3 V_{cc} - V_{cc}/2$) to exceed the reference levels causes the internal flip-flop to alternately set and reset, providing a square wave output as shown in Fig.



Input output waveforms of Schmitt Trigger

It may be noted that unlike conventional multivibrator, no frequency division is taking place and frequency of square wave remains the same as that of input signal.