Module 7	Special Function Ics (5)

IC 555 timer, Astable and Monostable operations, and applications. IC voltage regulator - LM317

IC555 - TIMER

IC555 - TIMER

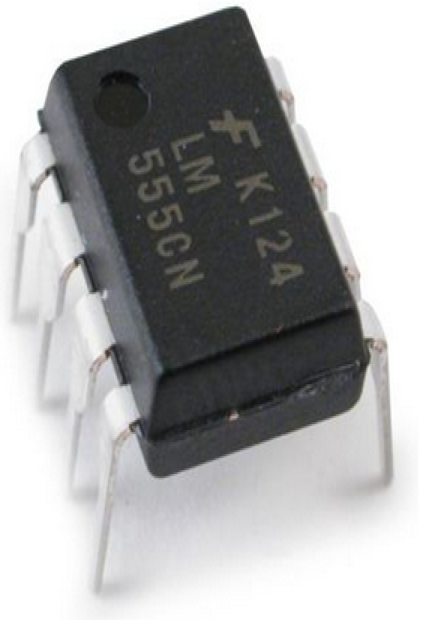
- The 555 timer IC was introduced in the year 1970 by Signetic Corporation and gave the name SE/NE 555 timer.
- It is basically a monolithic timing circuit that produces accurate and highly stable time delays or oscillation.
- Apart from its applications as a monostable multivibrator and astable multivibrator, a 555 timer can also be used in dc-dc converters, waveform generators, temperature measurement and control devices, voltage regulators etc.

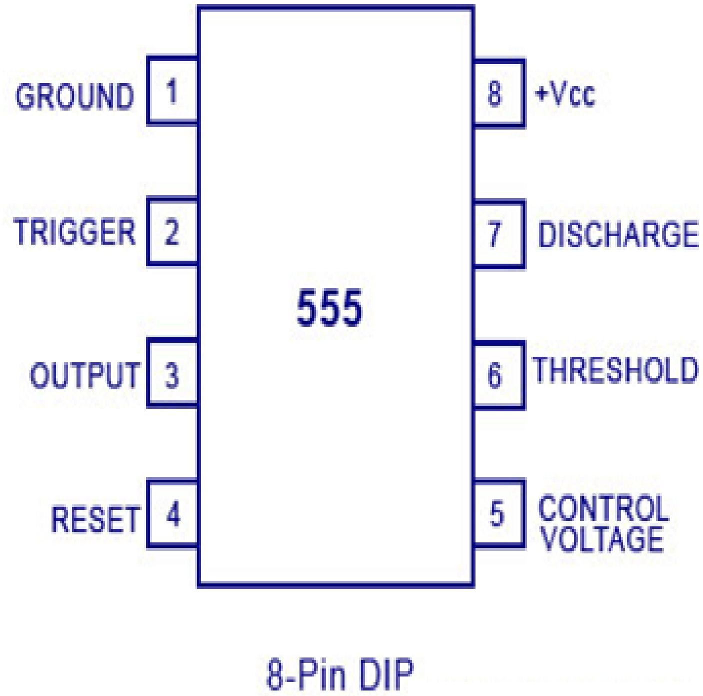
IC555 - TIMER

Features

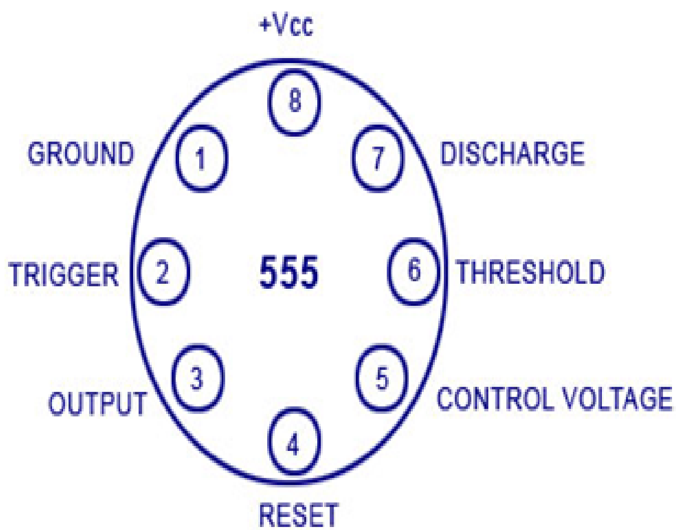
- To generate a time delay of few milliseconds to few hours
- It operates from a wide range of power supplies : + 5 V to + 18 V
- Two operating modes: Monostable & Astable
- Available IC packages: 8-pin Metal CAN, 8-Pin DIP, 14-Pin DIP
- It has a temperature stability, equivalently 0.005 %/ °C.
- Operating temperature range: -55°c to 125°c
- Sinking or sourcing 200 mA of load current.

IC555 - TIMER

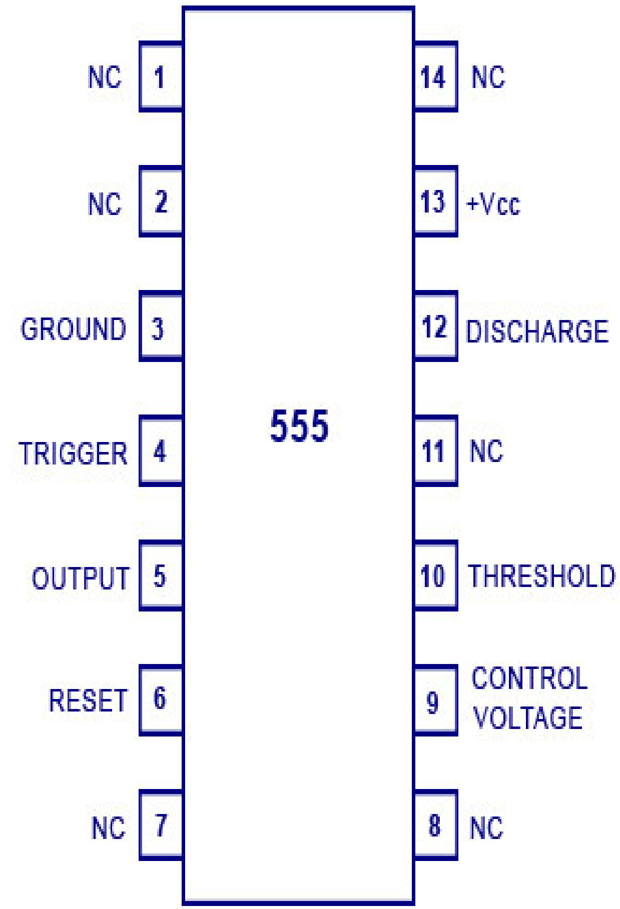

LM
555CN
K124


GROUND 1
TRIGGER 2
OUTPUT 3
RESET 4
8 +Vcc
7 DISCHARGE
6 THRESHOLD
5 CONTROL VOLTAGE
555
8-Pin DIP

IC555 - TIMER

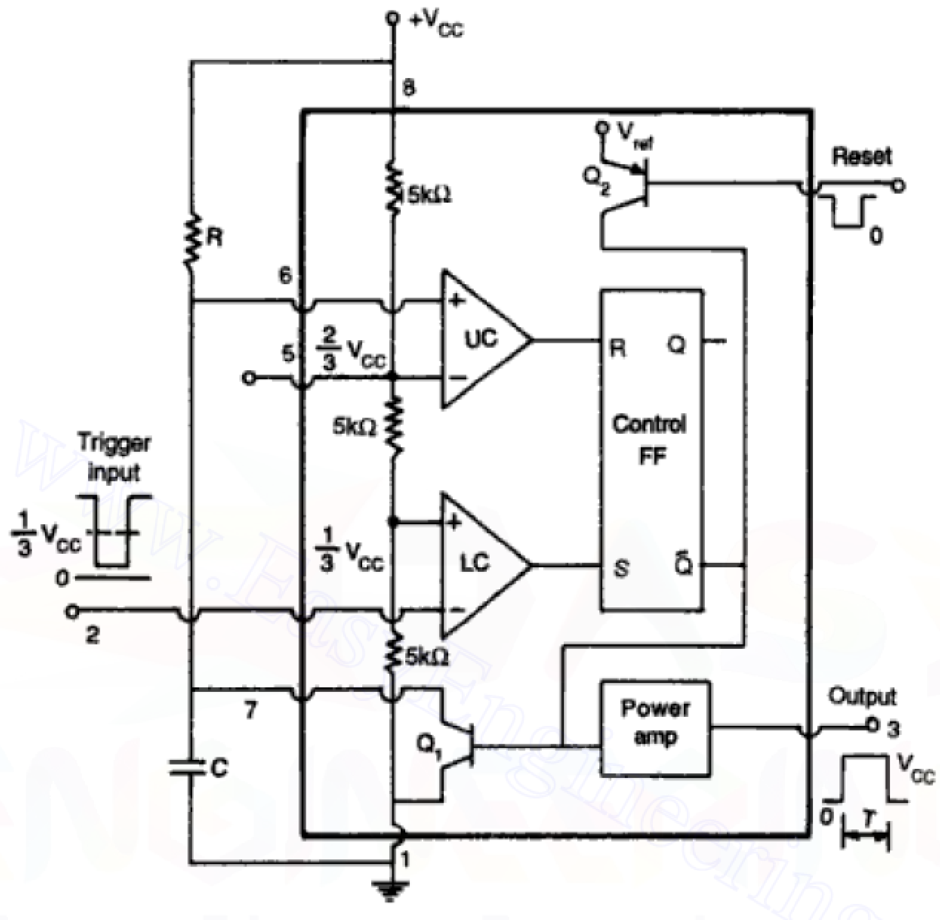


Top View Of Metal Can Package



14-Pin DIP

IC555 - TIMER



IC555 - BLOCK DIAGRAM

IC555 - TIMER

Pin Description

- Pin 1: Grounded Terminal: All the voltages are measured with respect to the Ground terminal.
- Pin 2: Trigger Terminal: The trigger pin is used to feed the trigger input then the 555 IC is set up as a monostable multivibrator.
- Pin 3: Output Terminal: Output of the timer is available at this pin.
- Pin 4: Reset Terminal: Whenever the timer IC is to be reset or disabled, a negative pulse is applied to pin 4.

IC555 - TIMER

Pin Description

- Pin 5: Control Voltage Terminal: The threshold and trigger levels are controlled using this pin.

- Pin 6: Threshold Terminal: This is the non-inverting input terminal of comparator 1, which compares the voltage applied to the terminal with a reference voltage of 2/3 V_{cc}.

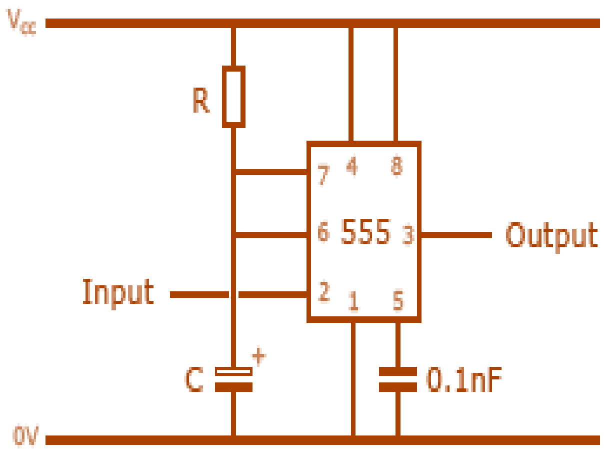
- Pin 7 : Discharge Terminal: This pin is connected to the collector of transistor and mostly a capacitor is connected between this terminal and ground.

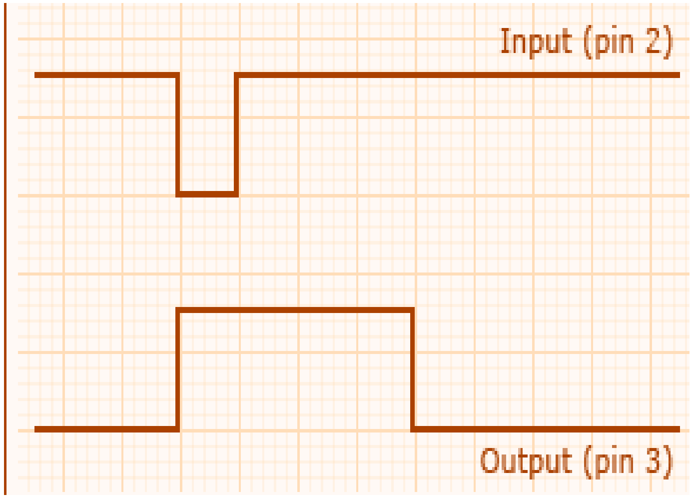
- Pin 8: Supply Terminal: A supply voltage of + 5 V to + 18 V is applied

IC555 - TIMER

Operating Modes

- **The most common types of outputs can be categorized by the following:**
  - **Monostable mode: in this mode, the 555 functions as a "one-shot". Applications include timers, missing pulse detection, bounce free switches, touch switches, frequency divider, capacitance measurement, pulse-width modulation (PWM) etc.**

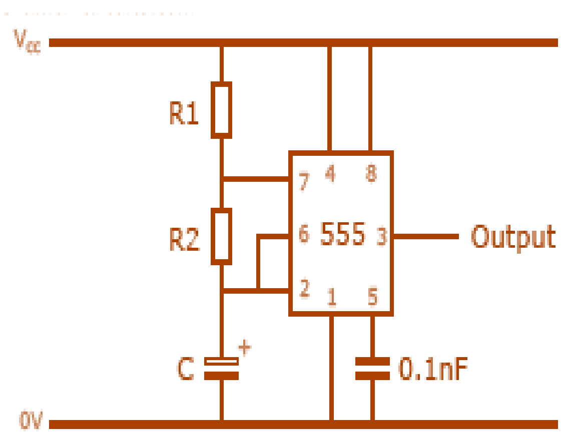


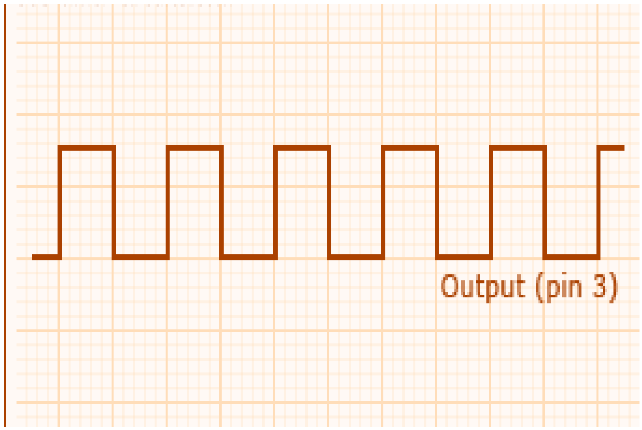


IC555 - TIMER

Operating Modes

- The most common types of outputs can be categorized by the following:
  - **Astable - free running mode:** the 555 can operate as an oscillator. Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, pulse position modulation, etc.



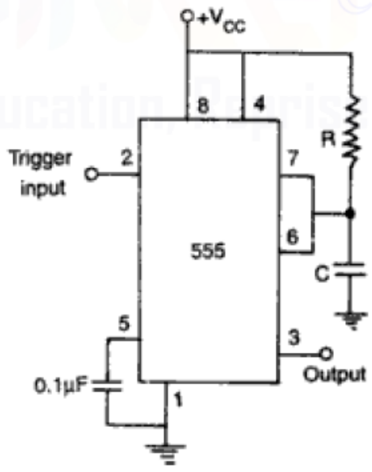


MONOSTABLE MULTIVIBRATO R

MONOSTABLE MULTIVIBRATOR

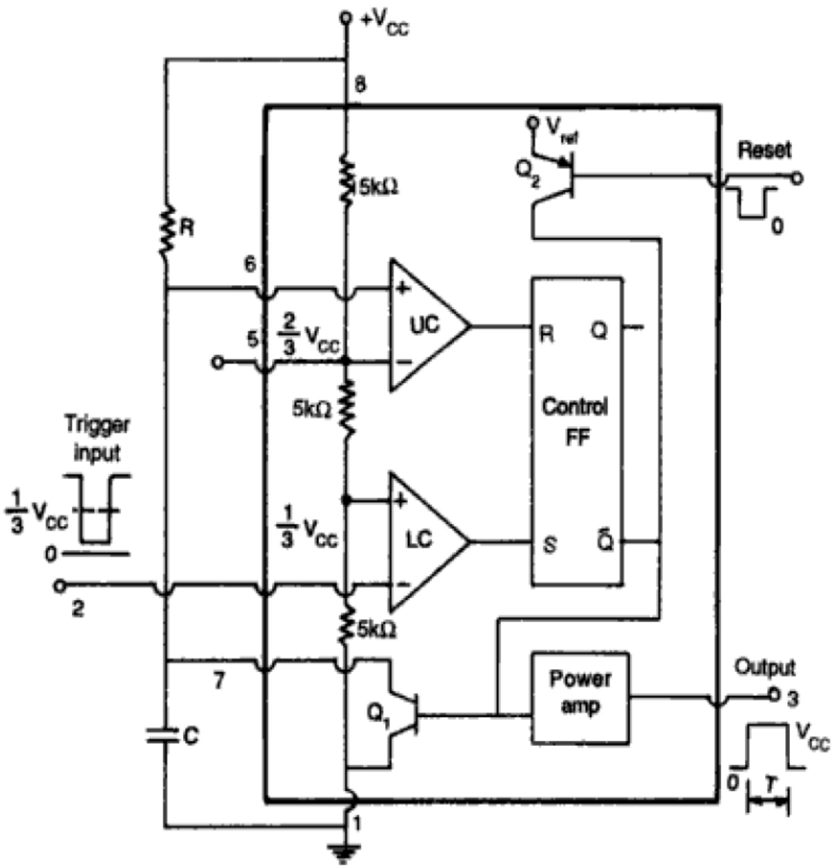
Monostable Multivibrator

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 R and C. As it has only one stable state, it is called one shot multivibrator.



MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator



MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator

- In monostable mode the 555 timer outputs a high pulse, which begins when the trigger pin is set low (less than 1/3Vcc, as explained in the previous step, this is enough to switch the output of the comparator connected to the trigger pin).

- The duration of this pulse is dependent on the values of the resistor R and capacitor C. When the trigger pin is high, it causes the discharge pin (pin 7) to drain all charge off the capacitor.

- This makes the voltage across the capacitor (voltage of pin 6) = 0

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator

- When the trigger pin gets flipped low, the discharge pin is no longer able to drain current, this causes charge to build up on the capacitor according to the equation below.

- Once the voltage across the capacitor (the voltage of pin 6) equals 2/3 of the supply voltage (again, as explained in the previous step, this is enough to switch the output of the comparator connected to pin 6), the output of the

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator

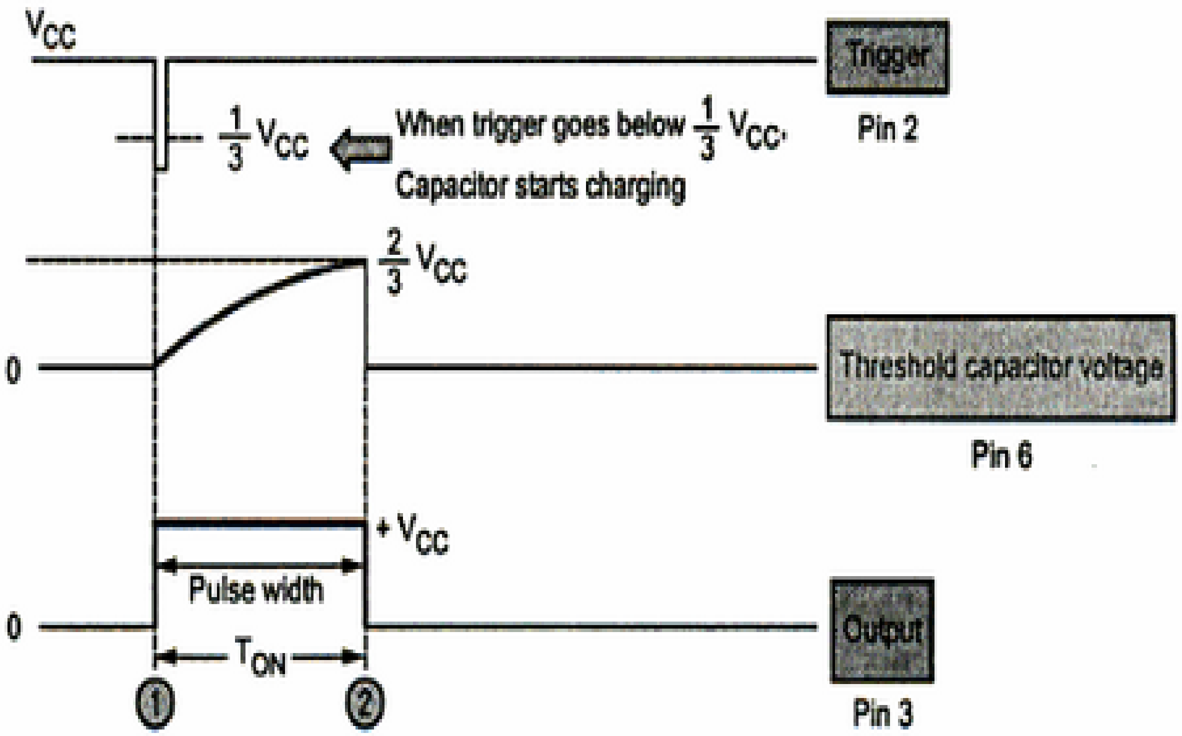


Fig. 4.11 Waveforms of monostable operation

Monostable Multivibrator

Derivation of Pulse Width

The voltage across capacitor increases exponentially and is given by

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

If $$V_C = 2/3\ V_{CC}$$

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

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

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

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

$\therefore$ $$t = +1.0986\ CR$$

$\therefore$ $$t \approx 1.1\ CR$$

where C in farads, R in ohms, t in seconds.

Thus, we can say that voltage across capacitor will reach 2/3 V_{CC} in approximately 1.1 times, time constant i.e. 1.1 RC

Thus the pulse width denoted as W is given by,

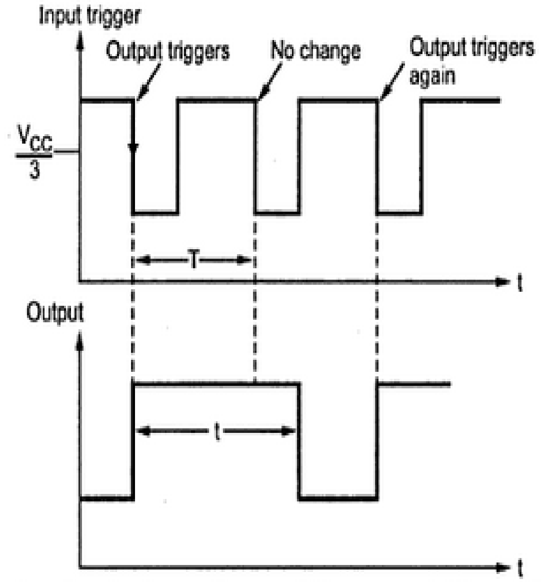
$$\boxed{W = 1.1\ RC}$$

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications

Frequency Divider

We know that, in monostable multivibrator, application of trigger pulse gives a positive going pulse on the output. The same monostable circuit can be used as a frequency divider if the timing interval is adjusted to be longer than the period of the input signal, as shown in the Fig.



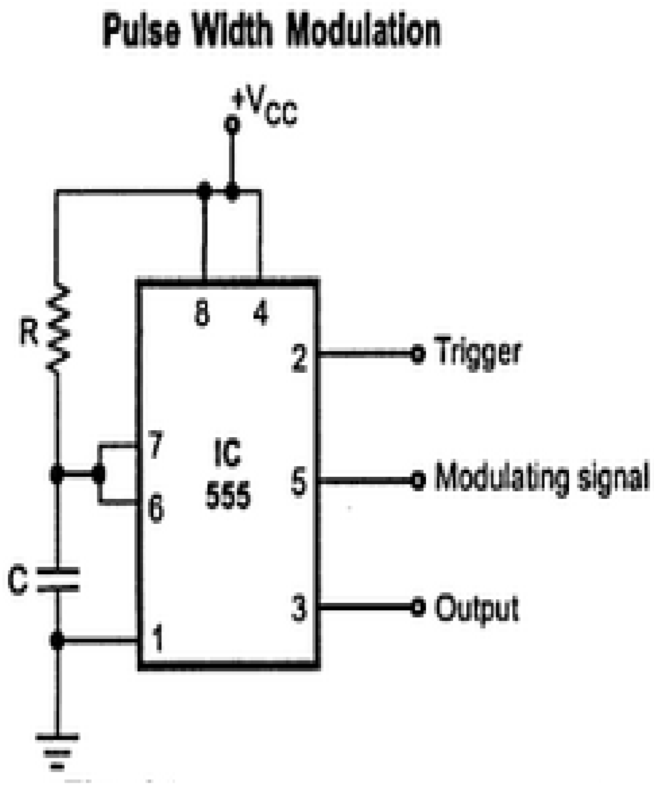
Input and output waveforms of the monostable multivibrator as a divide-by-2 circuit

Monostable Multivibrator - Applications

The monostable multivibrator will be triggered by the first negative going edge of the trigger input, which will make output to go in its high state. The output will remain high for the period equal to 'timing interval'. As timing interval is greater than time period of the trigger input, output will still be high when the second negative going pulse occurs. The monostable will, however, be re-triggered on the third negative-going pulse. Therefore, monostable triggers on every other pulse of the trigger input, so there is only one output for every two input pulses, thus trigger signal is, divided by 2.

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications



The Fig. shows pulse width modulator. It is basically a monostable multivibrator with a modulating input signal applied at the control voltage input (pin 5). Internally, the control voltage is adjusted to the 2/3 V_{CC}. Externally applied modulating signal changes the control voltage, and hence the threshold voltage level of the upper comparator (comparator 1). As a result, time period required to charge the capacitor upto threshold voltage level changes, giving pulse width modulated signal at the output as shown in the Fig

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications

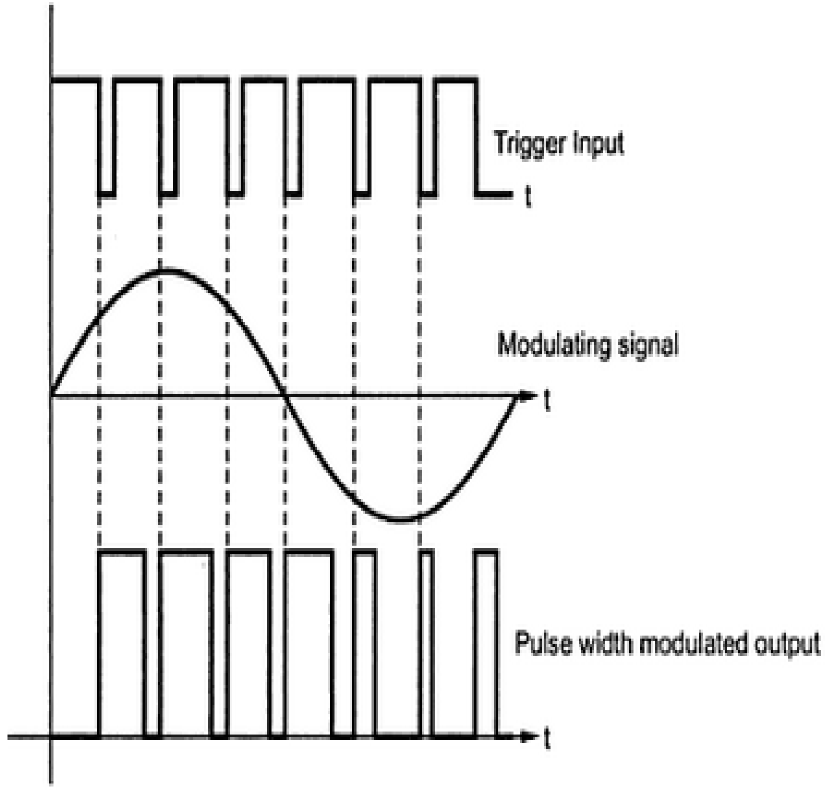


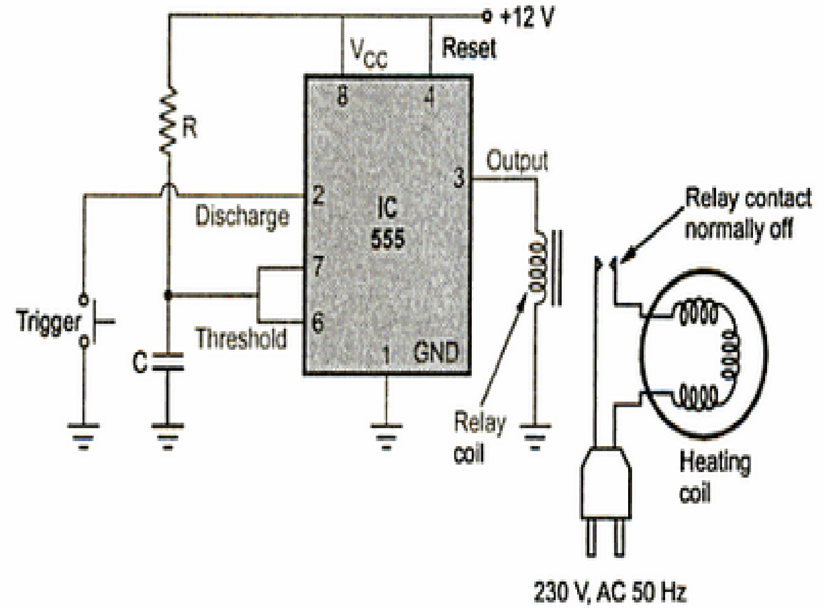
Fig. 4.16 Pulse width modulator waveforms

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications

Design a timer, which should turn ON heater immediately after pressing a push button and should hold heater in 'ON-state' for 5 seconds.

Solution : Fig. 4.21 shows monostable circuit used to drive the relay.



Monostable multivibrator used to switch 'ON' relay for specific time

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications

This relay should be energized for 5 seconds to hold heater 'ON' for 5 seconds. Thus, T_{ON} for monostable is 5 seconds.

We know that the pulse width is given by,

$$W = 1.1\,RC$$

$$\therefore \quad 5 = 1.1\,RC$$

Now, there are two unknowns. In this case, we have to select value for capacitor and with the selected value we have to find the value of resistance from the formula.

$\therefore$ If capacitor value is 10 μF

then
$$5 = 1.1 \times R \times 10\ \mu F$$

$$\therefore \quad R = \frac{5}{1.1 \times 10 \mu F}$$

$$= 454545.45\ \Omega = 454.54\ k\Omega$$

The calculated value is not standard value, but we can adjust this value by connecting variable resistance i.e. potentiometer.

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications

➠ *Draw the circuit diagram of Timer using IC 555. Calculate the component values if the controlled door should remain open for 15 secs after a trigger signal is received. The dc voltage available is either 10 or 15 volts.*

Solution : The requirement is that the door must be open for 15 sec after receiving a trigger signal and then gets shut down automatically. This requires IC 555 in a monostable mode with a pulse width of 15 sec.

$\therefore$ $W = 15$ sec

Now $W = 1.1\ RC$

$\therefore$ $15 = 1.1\ RC$

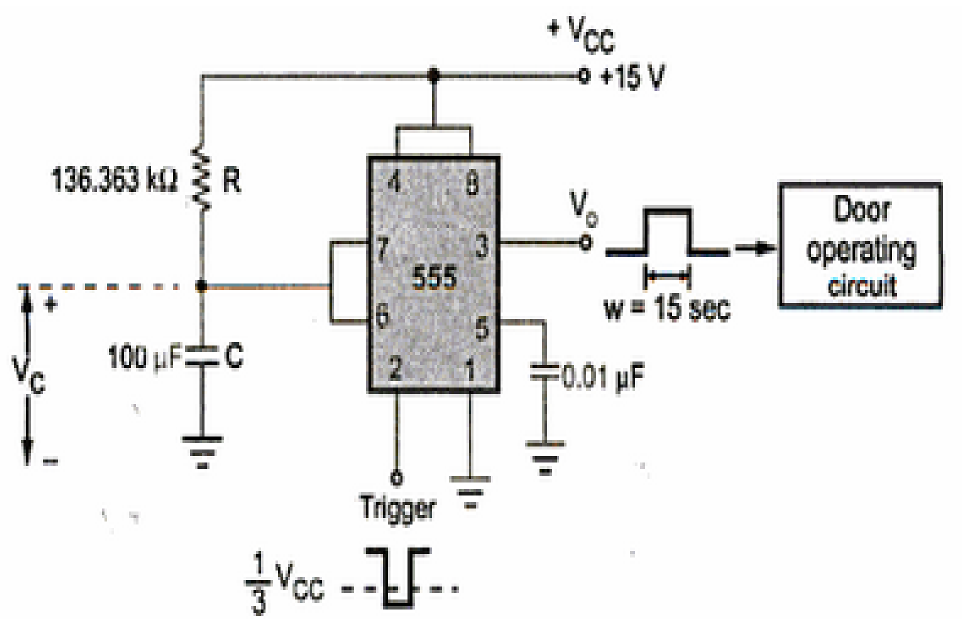
Choose $C = 100\ \mu F$

$\therefore$ $R = 136.363\ k\Omega$

The designed circuit is shown in the Fig.

MONOSTABLE MULTIVIBRATOR

Monostable Multivibrator - Applications



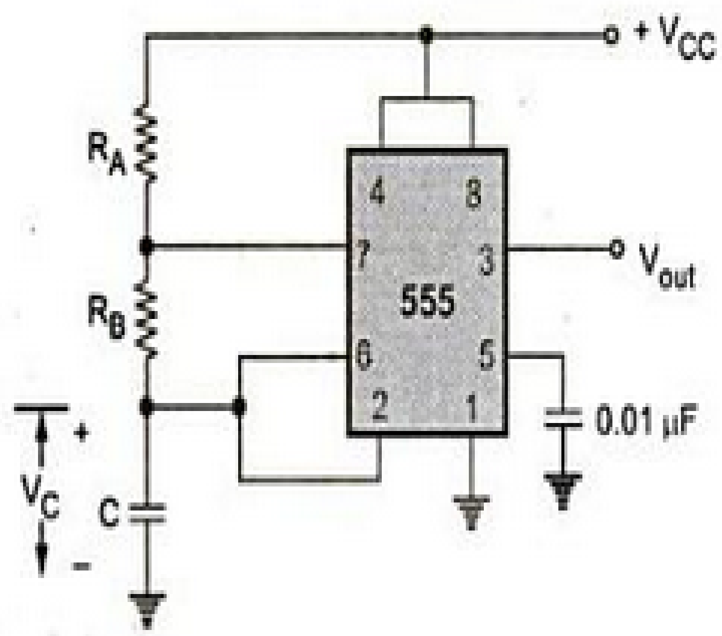
The supply voltage 10 or 15 V has no effect on the operation of the circuit or the values of R and C selected.

ASTABLE MULTIVIBRATO R

ASTABLE MULTIVIBRATOR

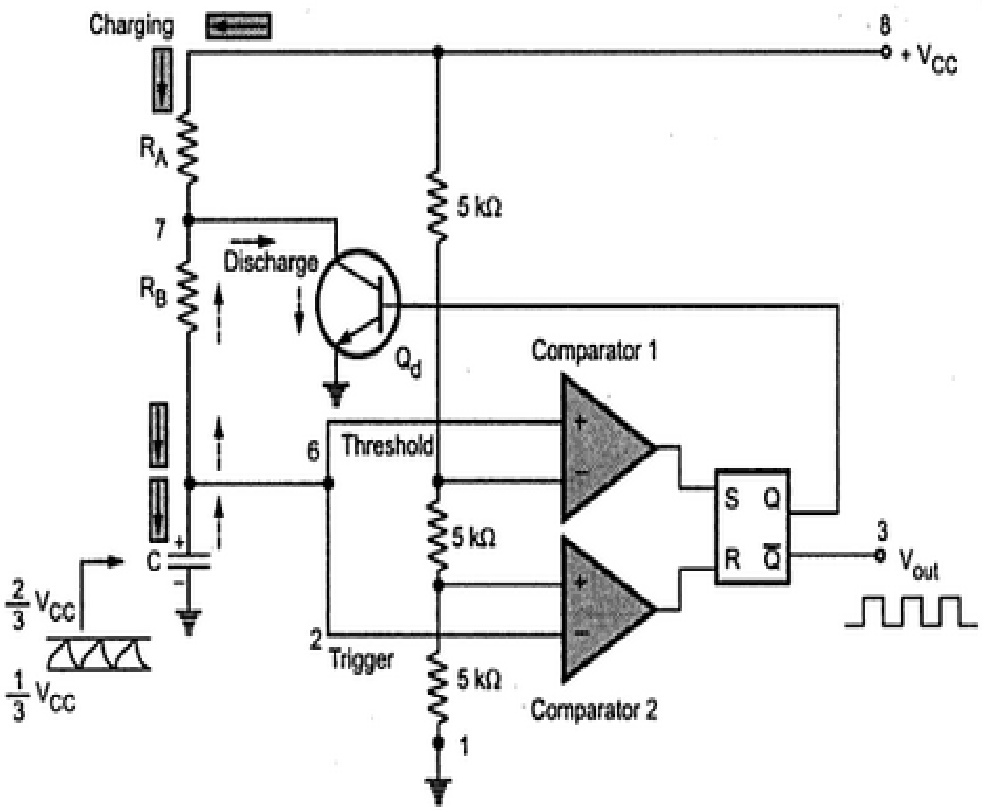
Astable Multivibrator

This circuit has no stable state. The circuits changes its state alternately. Hence the operation is also called free running nonsinusoidal oscillator.



ASTABLE MULTIVIBRATOR

Astable Multivibrator



Astable operation of 555

ASTABLE MULTIVIBRATOR

Astable Multivibrator

Operation

When the flip-flop is set, Q is high which drives the transistor Q_d in saturation and the capacitor gets discharged. Now the capacitor voltage is nothing but the trigger voltage. So while discharging, when it becomes less than 1/3 V_{CC}, comparator 2 output goes high. This resets the flip-flop hence Q goes low and $\bar{Q}$ goes high.

The low Q makes the transistor off. Thus capacitor starts charging through the resistances R_A, R_B and V_{CC}. The charging path is shown by thick arrows in the Fig.
As total resistance in the charging path is $(R_A + R_B)$, the charging time constant is $(R_A + R_B)\,C$.

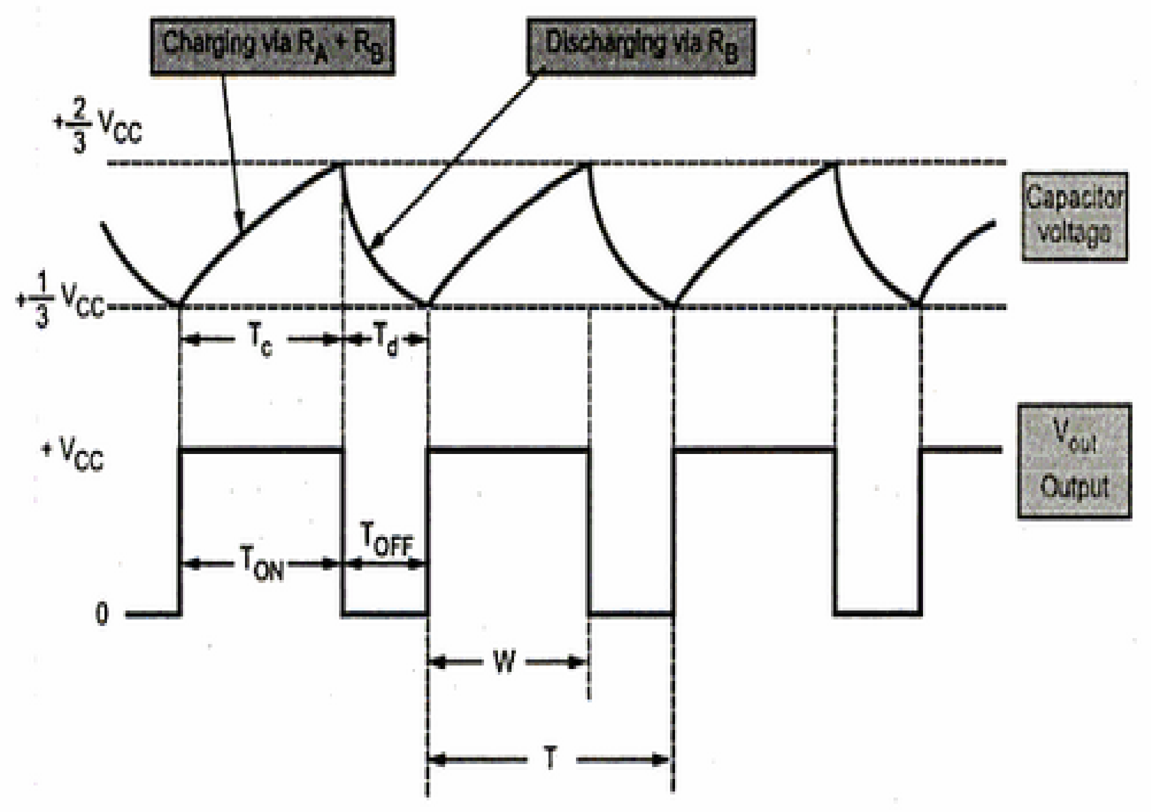
ASTABLE MULTIVIBRATOR

Astable Multivibrator

Now the capacitor voltage is also a threshold voltage. While charging, capacitor voltage increases i.e. the threshold voltage increases. When it exceeds 2/3 V_{CC}, then the comparator 1 output goes high which sets the flip-flop. The flip-flop output Q becomes high and output at pin 3 i.e. $\bar{Q}$ becomes low. High Q drives transistor Q_d in saturation and capacitor starts discharging through resistance R_B and transistor Q_d. This path is shown by dotted arrows in the Fig. . Thus the discharging time constant is R_B C. When capacitor voltage becomes less than 1/3 V_{CC}, comparator 2 output goes high, resetting the flip-flop. This cycle repeats.

ASTABLE MULTIVIBRATOR

Astable Multivibrator



Waveforms of astable operation

ASTABLE MULTIVIBRATOR

Astable Multivibrator

Duty Cycle

Generally the charging time constant is greater than the discharging time constant. Hence at the output, the waveform is not symmetric. The high output remains for longer period than low output. The ratio of high output period and low output period is given by a mathematical parameter called duty cycle. It is defined as the ratio of ON time i.e. high output to the total time of one cycle. As shown in the Fig.

$$W = \text{time for output is high} = T_{ON}$$

$$T = \text{time of one cycle}$$

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

$$\therefore \quad \boxed{\%D = \frac{W}{T} \times 100\,\%}$$

The charging time for the capacitor is given by,

$$T_c = \text{Charging time} = 0.693\,(R_A + R_B)\,C$$

While the discharge time is given by,

$$T_d = \text{Discharging time} = 0.693\,R_B\,C$$

ASTABLE MULTIVIBRATOR

Astable Multivibrator

Hence the time for one cycle is,

$$T = T_c + T_d = 0.693\,(R_A + R_B)\,C + 0.693\,R_B\,C$$

$$\therefore \quad \boxed{T = 0.693\,(R_A + 2R_B)\,C}$$

while $$W = T_c = 0.693\,(R_A + R_B)\,C$$

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

$$\therefore \quad \boxed{\%\,D = \frac{(R_A + R_B)}{(R_A + 2R_B)} \times 100}$$

While the frequency of oscillations is given by,

$$f = \frac{1}{T} = \frac{1}{0.693(R_A + 2R_B)C}$$

$$\therefore \quad \boxed{f = \frac{1.44}{(R_A + 2R_B)C}\ \text{Hz}}$$

If R_A is much smaller than R_B, duty cycle approaches to 50% and output waveform approaches to square wave.

ASTABLE MULTIVIBRATOR

Astable Multivibrator

➠ *A 555 timer is configured to run in astable mode with $R_A = 4\ k\Omega$, $R_B = 4\ k\Omega$ and $C = 0.01\ \mu F$. Determine the frequency of the output and duty cycle.*

Solution : The frequency of output is given by,

$$f = \frac{1.44}{(R_A + 2R_B)C} = \frac{1.44}{(4+2\times 4)\times 10^3 \times 0.01 \times 10^{-6}}$$

$$= \mathbf{12\ kHz}$$

The duty cycle is given by,

$$D = \frac{R_A + R_B}{R_A + 2R_B}$$

$$= \frac{4+4}{4+(2\times 4)} = 0.6667$$

Thus the duty cycle is **66.67%**.

ASTABLE MULTIVIBRATOR

Astable Multivibrator

An astable multivibrator is to be designed for getting rectangular waveform with $t_{ON} = 0.6$ ms. Draw the circuit diagram with various component values. Also calculate frequency of oscillations and duty cycle. Assume total time period (T) to be 1 ms.

Solution : $T_{ON} = 0.6$ ms, $T = 1$ ms

$$\therefore \quad D = \frac{t_{ON}}{T} = \frac{0.6}{1} = 60\%$$

$$\text{Now} \quad D = \frac{R_A + R_B}{R_A + 2R_B} = 0.6$$

$$\therefore \quad R_A + R_B = 0.6\,R_A + 1.2\,R_B$$

$$\therefore \quad 0.4\,R_A = 0.2\,R_B$$

$$\therefore \quad R_B = 2\,R_A$$

$$f = \frac{1.44}{(R_A + 2R_B)C} = \frac{1}{T} = 1000$$

$$\text{Choose } C = 0.1\ \mu F$$

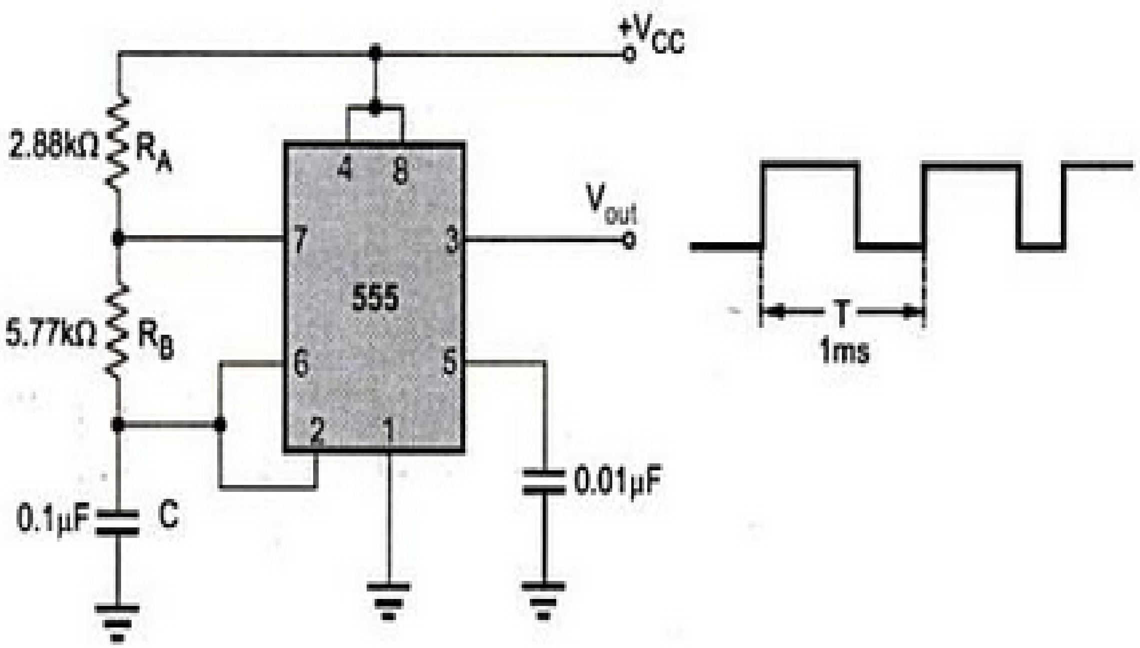
$$\therefore \quad R_A + 2R_B = 14400$$

$$\text{Using (1), } 5R_A = 14400$$

$$\therefore \quad R_A = 2.88\ k\Omega, \quad R_B = 5.77\ k\Omega$$

ASTABLE MULTIVIBRATOR

Astable Multivibrator

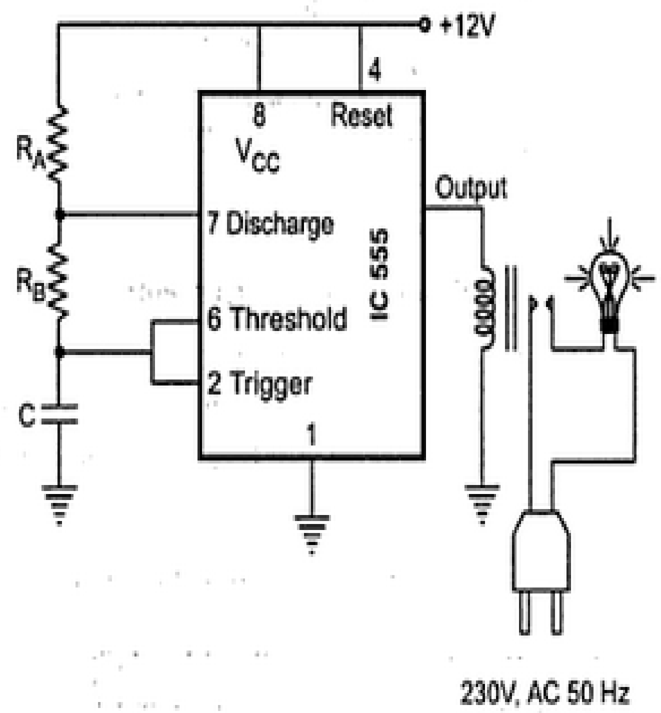


ASTABLE MULTIVIBRATOR

Astable Multivibrator

Design an astable multivibrator which will flash the electric bulb such that its ON time will be 3 seconds and off time will be 1 seconds.

Solution : Fig. 4.27 shows astable circuit used to drive relay.



ASTABLE MULTIVIBRATOR

Astable Multivibrator

This relay should be energized for 3 seconds and then de-energize by 1 seconds.

Hence charging time of capacitor is 3 seconds which is a pulse width W.

$$\therefore \quad W = 3 \text{ seconds}$$

While total time of one cycle is,

$$\therefore \quad T = 3 + 1 = 4 \text{ seconds}$$

$$\therefore \quad D = \frac{W}{T} = \frac{3}{4} = \text{duty cycle} = 0.75$$

But
$$D = \frac{R_A + R_B}{R_A + 2R_B}$$

$$\therefore \quad 0.75 = \frac{R_A + R_B}{R_A + 2R_B}$$

$$\therefore \quad R_A + 2R_B = 1.33R_A + 1.33R_B$$

$$\therefore \quad 0.667 R_B = 0.333 R_A$$

$$\therefore \quad R_A = 2R_B \qquad \ldots (1)$$

Now the charging time is given by,

$$T_c = 0.693 (R_A + R_B) C$$

$$\therefore \quad 3 = 0.693 (R_A + R_B) C$$

Choose
$$C = 10 \, \mu F$$

ASTABLE MULTIVIBRATOR

Comparison of Multivibrator Circuits

Sr. No.	Monostable multivibrator	Astable multivibrator
1.	It has only one stable state.	There is no stable state.
2.	Trigger is required for the operation, to change the state.	Trigger is not required to change the state, hence called free running.
3.	Two components R and C are necessary with IC 555 to obtain the circuit.	Three components R_A, R_B and C are necessary with IC 555 to obtain the circuit.
4.	The pulse width is given by, W = 1.1 RC seconds	The frequency is given by, $f = \frac{1.44}{(R_A + 2R_B)}$ Hz
5.	The frequency of operation is controlled by frequency of trigger pulses applied.	The frequency of operation is controlled by R_A, R_B and C.
6.	The applications are, timer, frequency divider, pulse width modulation etc.	The applications are square wave generator, flasher, voltage controlled oscillator, FSK generator etc.