Rizvi College Of Arts, Science and Commerce

Subject : Bifocal Electronics

Standard : XII
Paper : I

Chapter : 6

Topic : IC 555

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Dept : Electronics – Junior College

XII P1 Chapter No.06

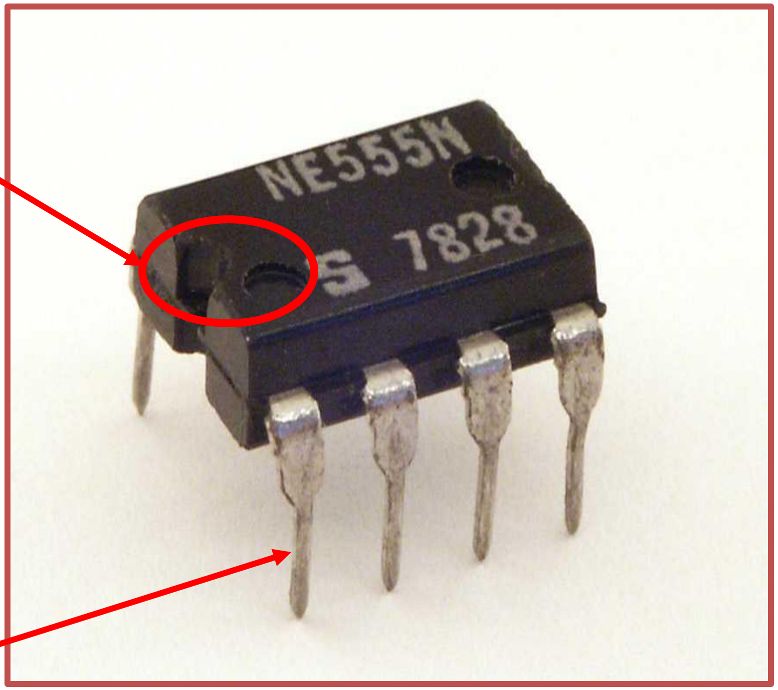
555 TIMER

By Safdar Ulde

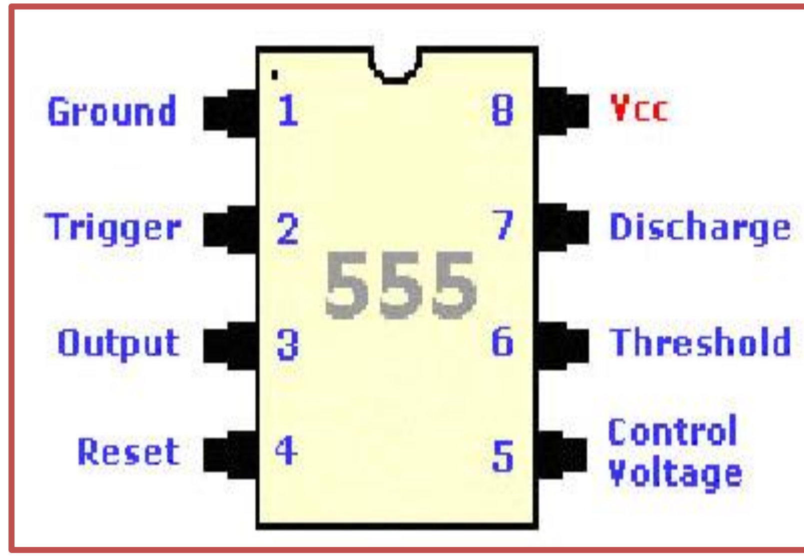
Have you seen this IC ?
555 timer- Pin Diagram

The 555 timer is an 8-Pin D.I.L. Integrated Circuit or ‘chip’

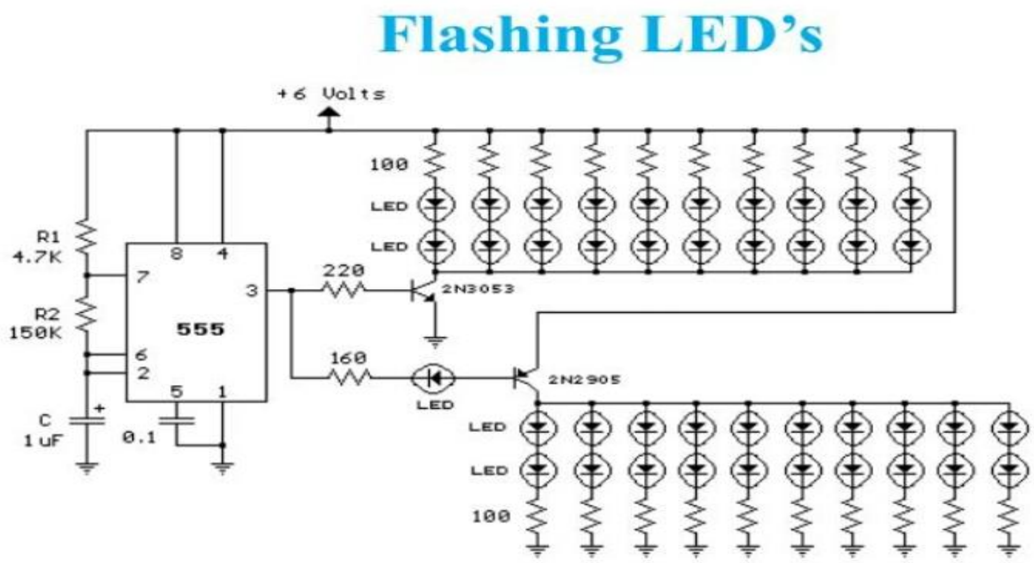
Notch



Pin 1

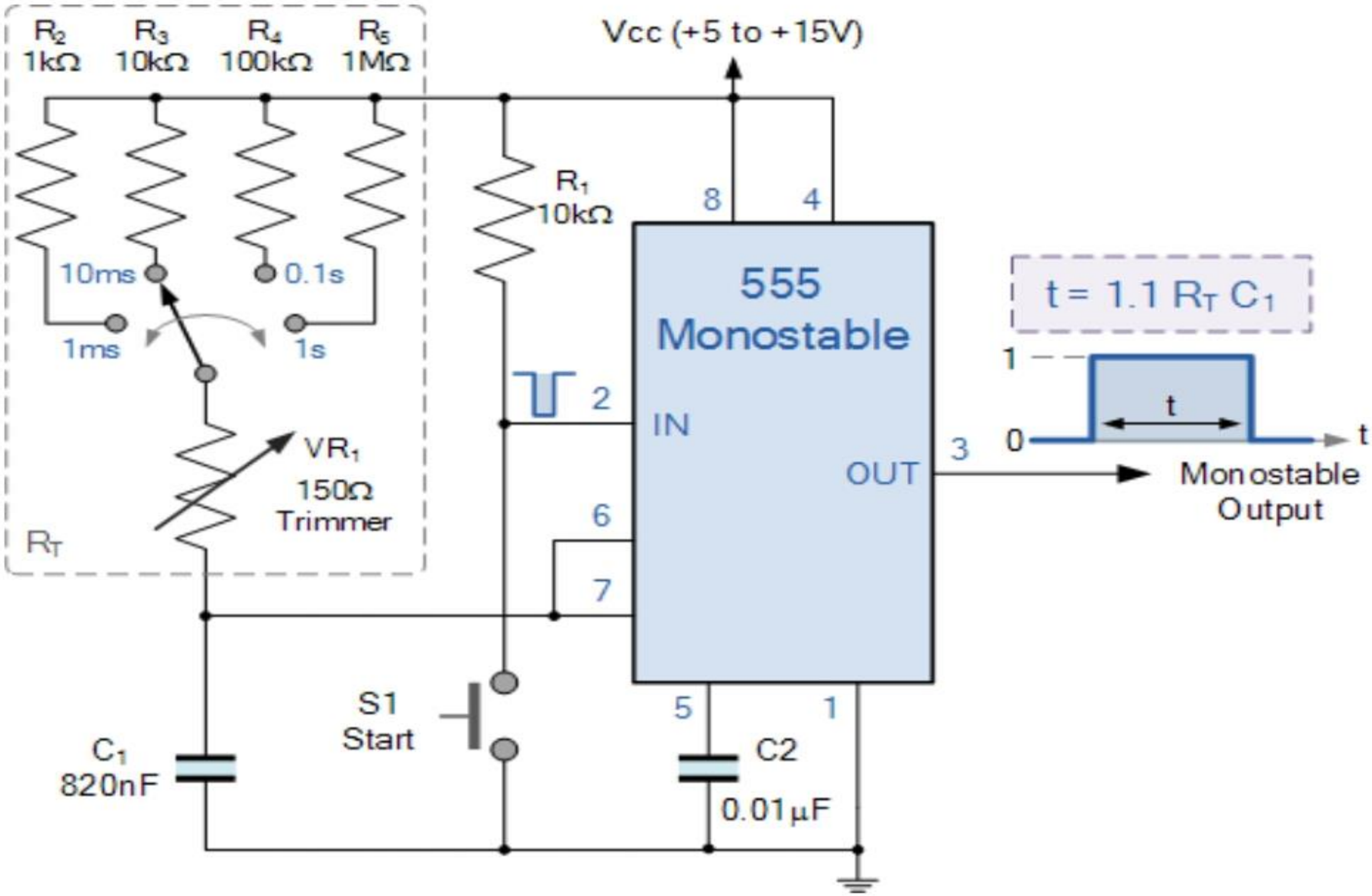


Application of IC 555- Timer IC



- 40 LED bicycle light with 20 LEDs flashing alternately at 4.7Hz

A Switchable 555 Timer



What is the 555 timer?

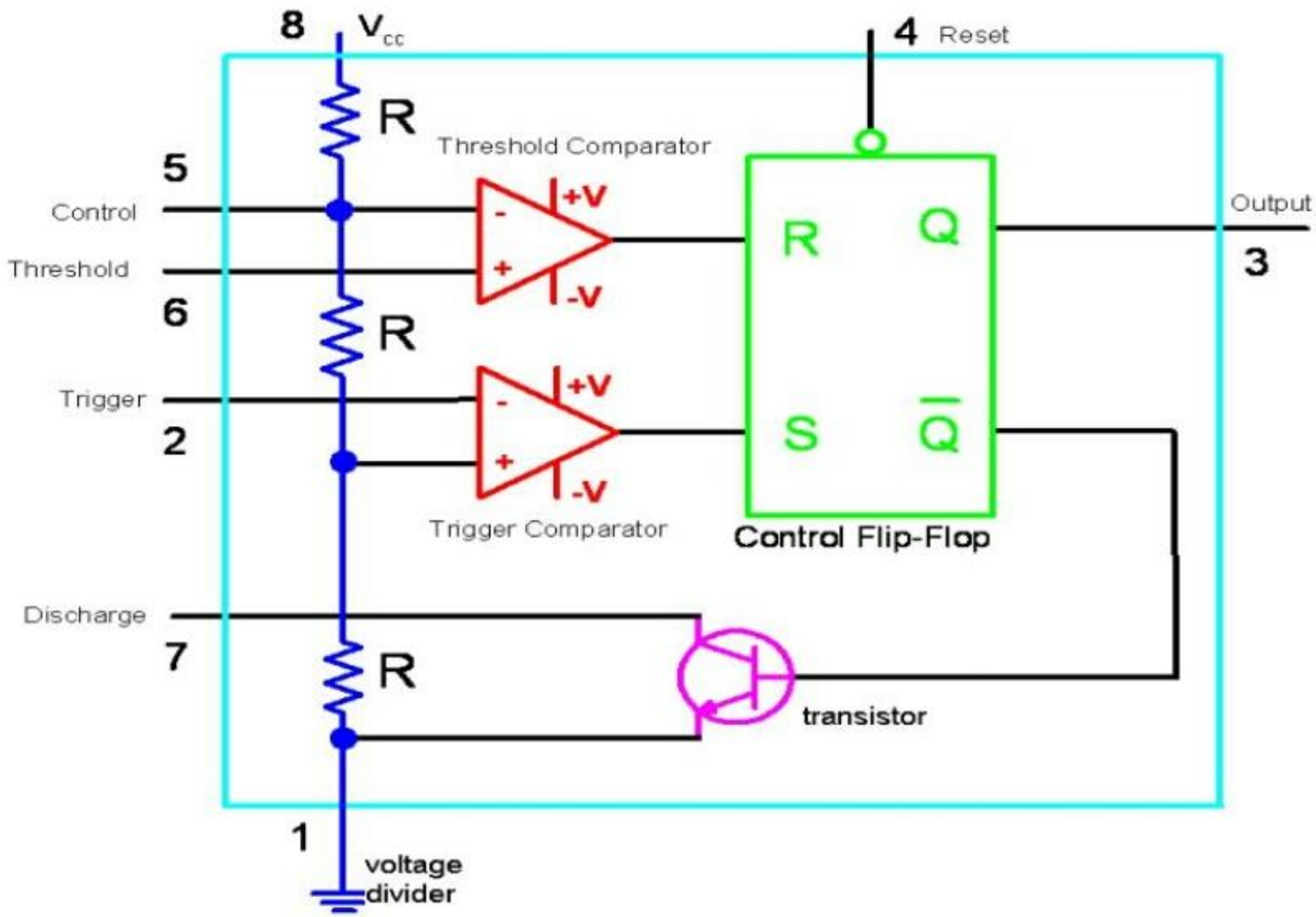
- The 555 timer is one of the most remarkable integrated circuits ever developed. It comes in a single or dual package and even low power cmos versions exist - ICM7555.
- Common part numbers are LM555, NE555, LM556, NE556. The 555 timer consists of two voltage comparators, a bi-stable flip flop, a discharge transistor, and a resistor divider network.

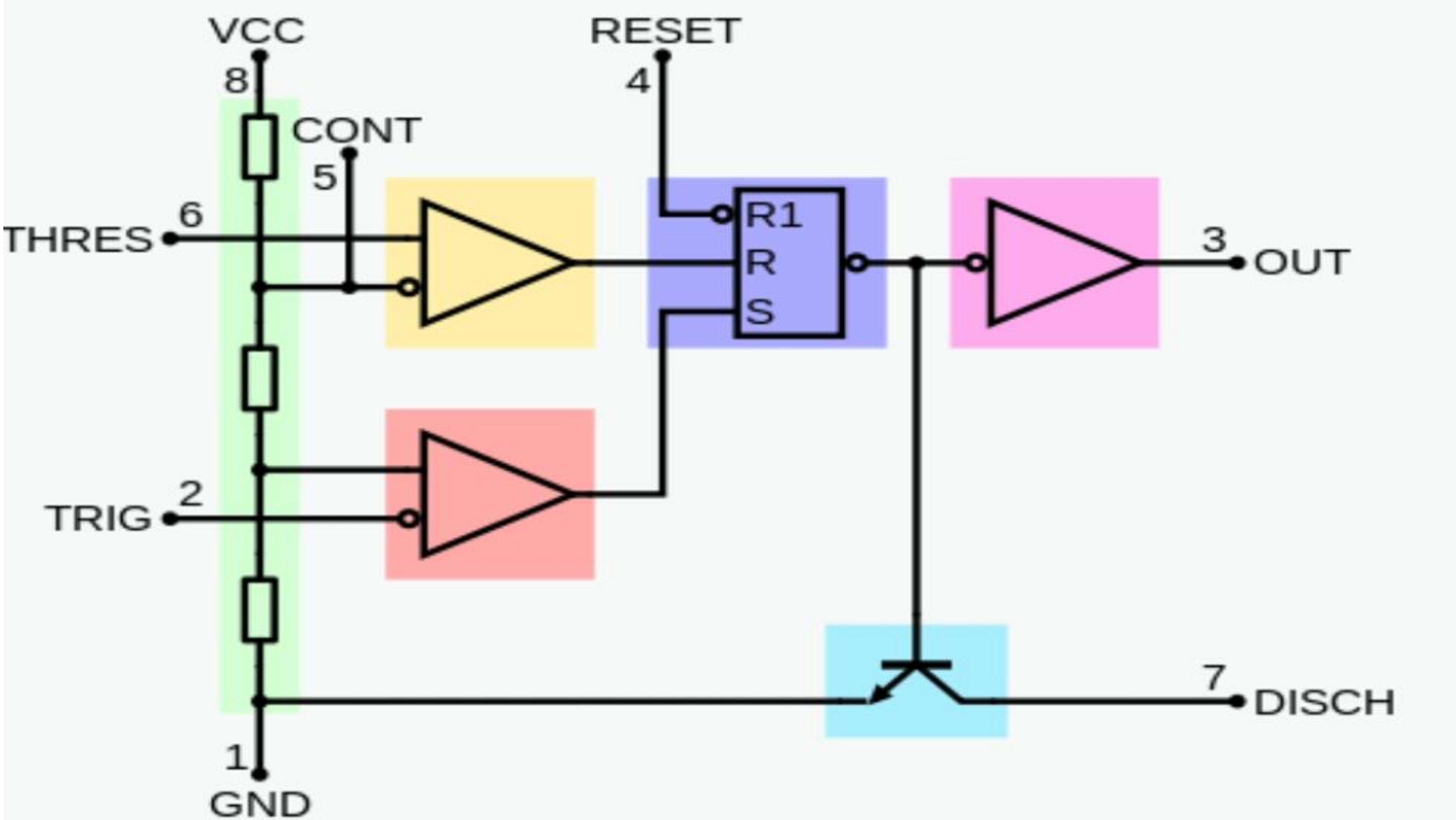
555 Timer

Introduction:

- The 555 Timer is one of the most popular and versatile integrated circuits ever produced!
- "Signetics" Corporation first introduced this device as the SE/NE 555 in early 1970.
- It is a combination of digital and analog circuits.
- It is known as the "time machine" as it performs a wide variety of timing tasks.
- Applications for the 555 Timer include:
  - Ramp and Square wave generator
  - Frequency dividers
  - Voltage-controlled oscillators
  - Pulse generators and LED flashers

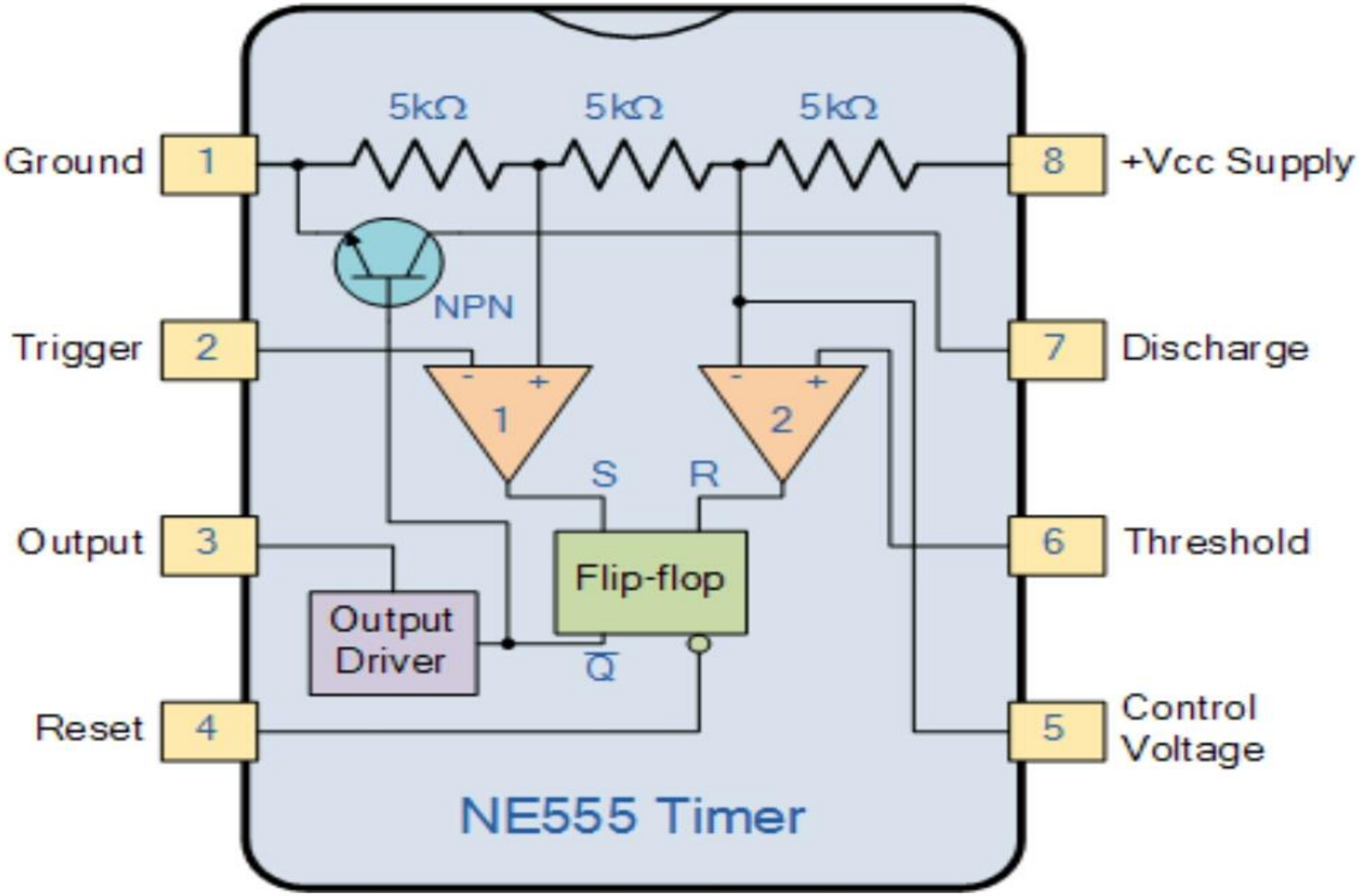
Block Diagram of Timer 555 IC





Internal block diagram[1]

555 Timer Block Diagram



Inside the 555 Timer

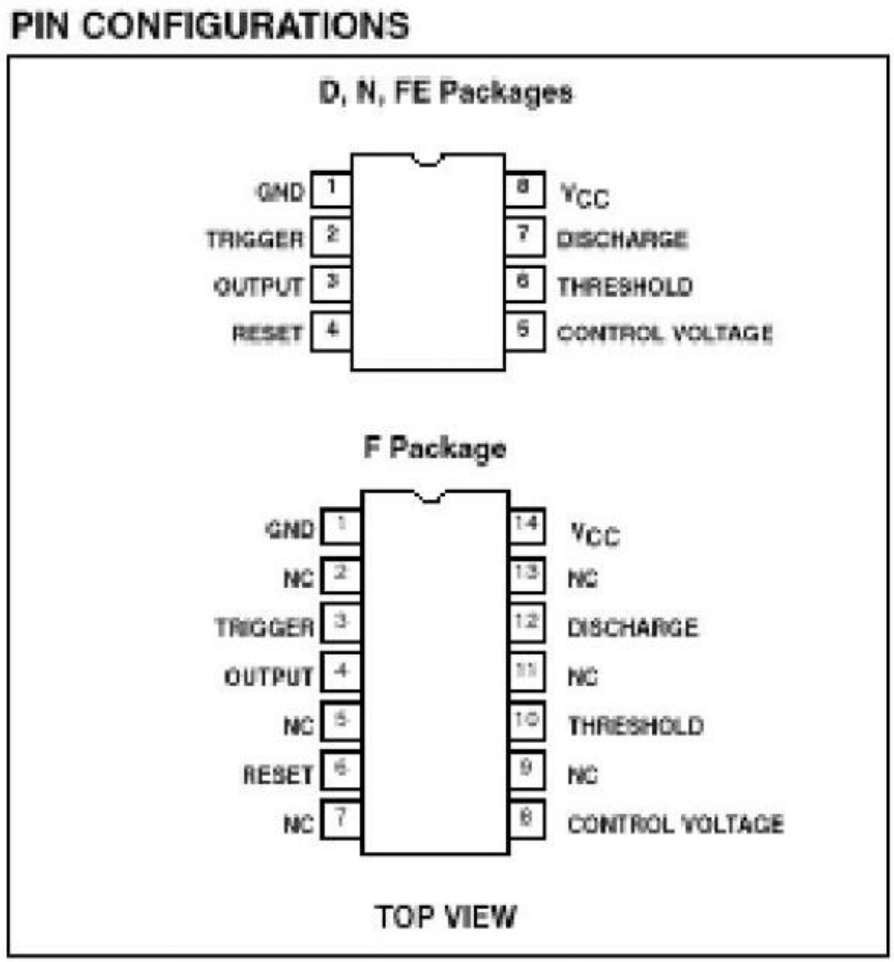
- The voltage divider (blue) has three equal 5K resistors. It divides the input voltage (Vcc) into three equal parts.
- The two comparators (red) are op-amps that compare the voltages at their inputs and saturate depending upon which is greater.
    - The Threshold Comparator saturates when the voltage at the Threshold pin (pin 6) is greater than (2/3)Vcc.
    - The Trigger Comparator saturates when the voltage at the Trigger pin (pin 2) is less than (1/3)Vcc

- The flip-flop (green) is a bi-stable device. It generates two values, a "high" value equal to Vcc and a "low" value equal to 0V.
  - When the Threshold comparator saturates, the flip flop is Reset (R) and it outputs a low signal at pin 3.
  - When the Trigger comparator saturates, the flip flop is Set (S) and it outputs a high signal at pin 3.
- The transistor (purple) is being used as a switch, it connects pin 7 (discharge) to ground when it is closed.
  - When Q is low, Qbar is high. This closes the transistor switch and attaches pin 7 to ground.
  - When Q is high, Qbar is low. This open the switch and pin 7 is no longer grounded

What are the 555 timer applications?

- Applications include
  - precision timing,
  - pulse generation,
  - sequential timing,
  - time delay generation and pulse width modulation (PWM).

Pin configurations of the 555 timer



555 timer- Pin Description

Pin	Name	Purpose
1	GND	Ground, low level (0 V)
2	TRIG	OUT rises, and interval starts, when this input falls below 1/3 V_{CC}.
3	OUT	This output is driven to approximately 1.7V below $+V_{CC}$ or GND.
4	RESET	A timing interval may be reset by driving this input to GND, but the timing does not begin again until RESET rises above approximately 0.7 volts. Overrides TRIG which overrides THR.
5	CTRL	"Control" access to the internal voltage divider (by default, 2/3 V_{CC}).
6	THR	The interval ends when the voltage at THR is greater than at CTRL.
7	DIS	Open collector output; may discharge a capacitor between intervals. In phase with output.
8	$V+$, V_{CC}	Positive supply voltage is usually between 3 and 15 V.

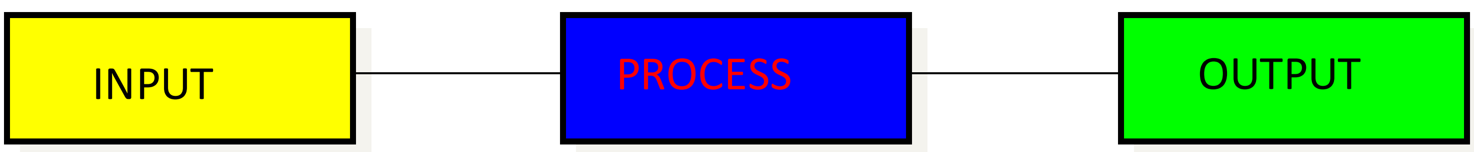
- **Pin Functions - 8 pin package**
- **Ground (Pin 1)**
- Not surprising this pin is connected directly to ground.
- **Trigger (Pin 2)**
- This pin is the input to the lower comparator and is used to set the latch, which in turn causes the output to go high.
- **Output (Pin 3)**
- Output high is about 1.7V less than supply. Output high is capable of $\mathbf{I}_{source}$ up to 200mA while output low is capable of $\mathbf{I}_{sink}$ up to 200mA.
- **Reset (Pin 4)**
- This is used to reset the latch and return the output to a low state. The reset is an overriding function. When not used connect to V+.

- **Control (Pin 5)**
- Allows access to the 2/3V+ voltage divider point when the 555 timer is used in voltage control mode. When not used connect to ground through a 0.01 uF capacitor.
- **Threshold (Pin 6)**
- This is an input to the upper comparator.
- **Discharge (Pin 7)**
- This is the open collector to Q14 in figure 4 below.
- **V+ (Pin 8)**
- This connects to Vcc and the Philips databook states the ICM7555 cmos version operates 3V - 16V DC while the NE555 version is 3V - 16V DC. Note comments about effective supply filtering and bypassing this pin below under "General considerations with using a 555 timer"

555 Timer

Description:

- Contains 25 transistors, 2 diodes and 16 resistors
- Maximum operating voltage 16V
- Maximum output current 200mA
- Best treated as a single component with required input and output



If you input certain signals they will be processed / controlled in a certain manner and will produce a known output.

Inside the 555 Timer Rev

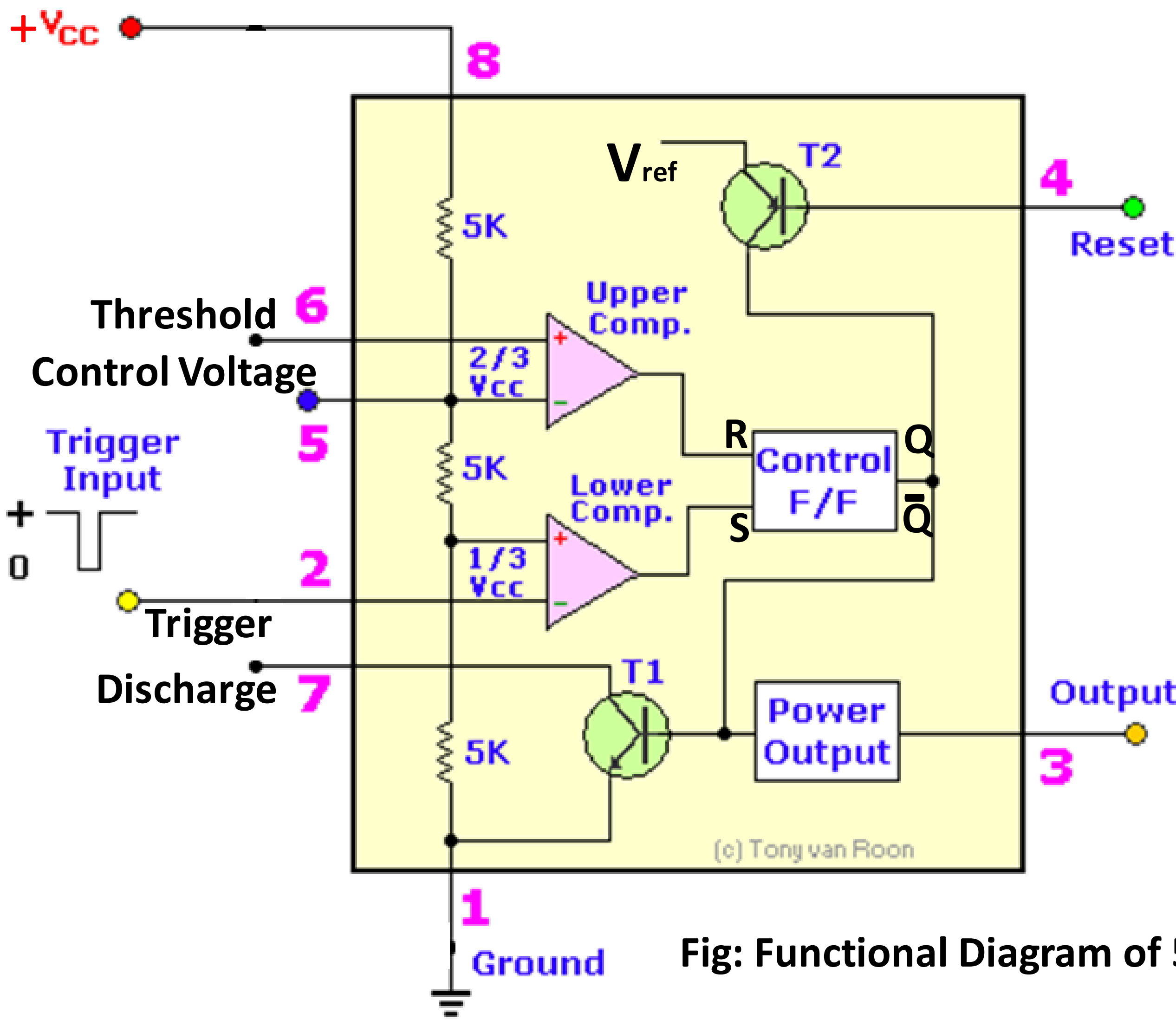
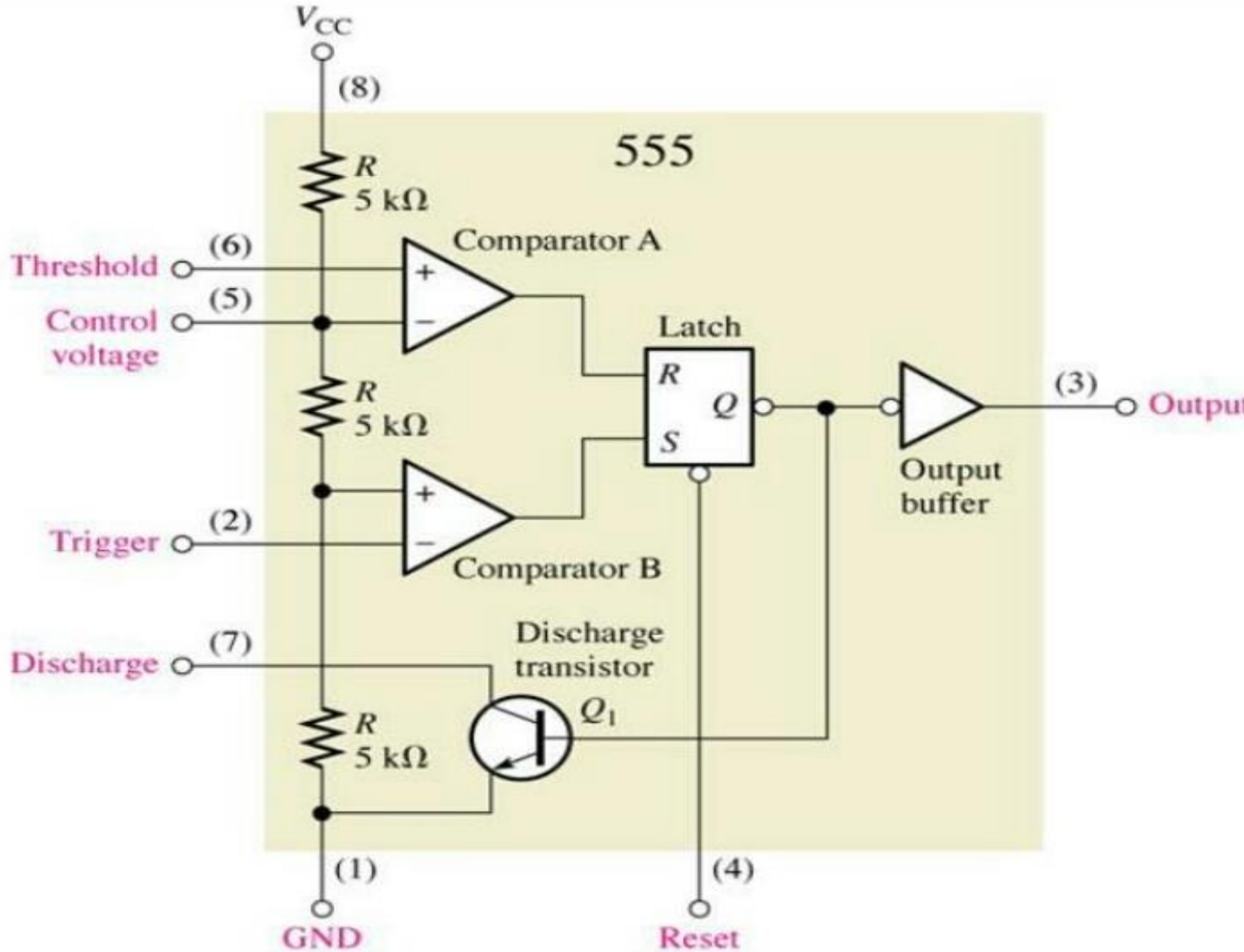


Fig: Functional Diagram of 555 Timer

Truth Table

S	R	Q	Q
0	0	No Change	
0	1	0	1
1	0	1	0
1	1	X	X

Functional Diagram of 555 Timer



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Operation:

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Uses of 555 timer

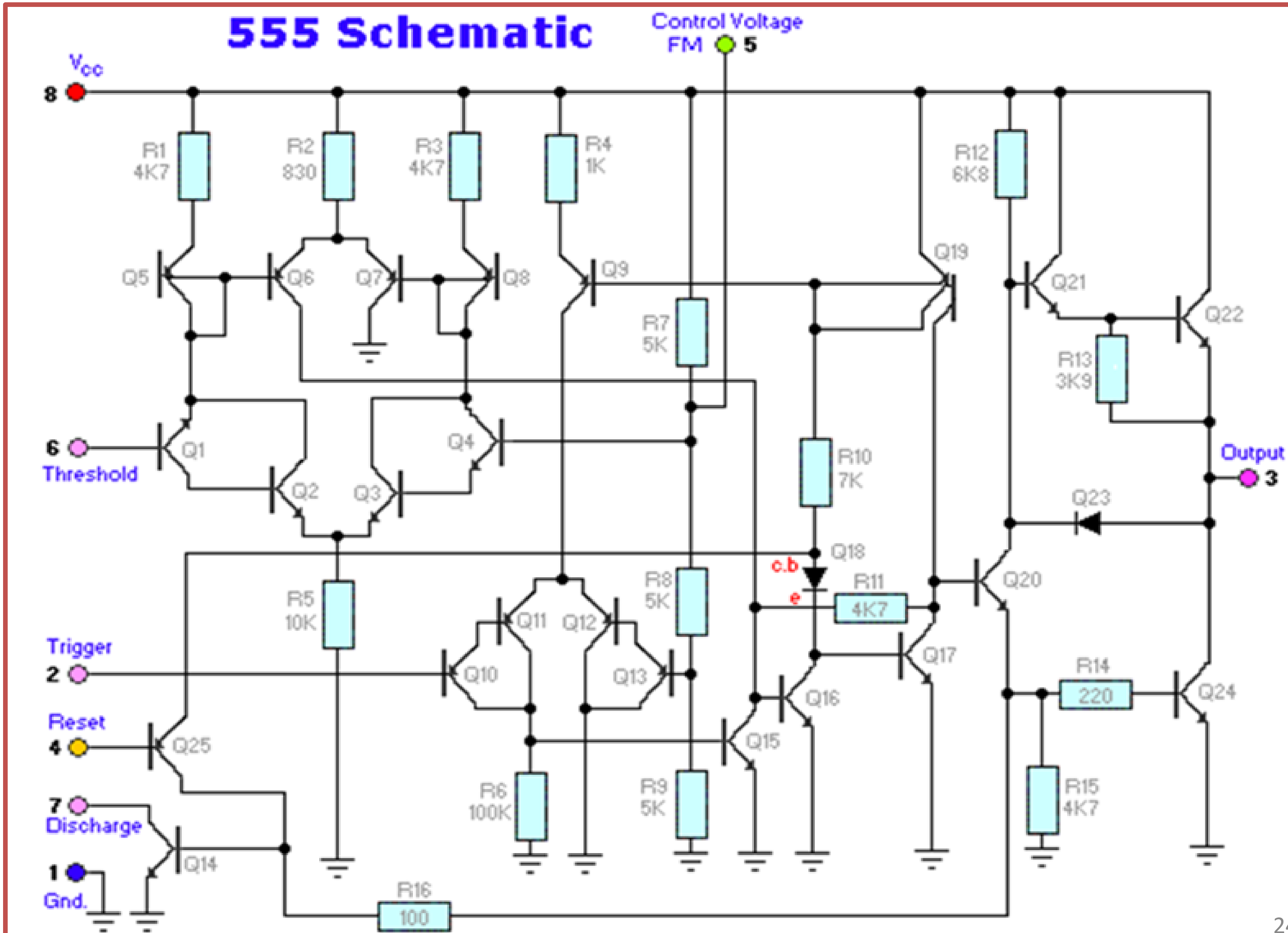
What the 555 timer is used for:

- To switch on or off an output after a certain time delay i.e.
  Games timer, Childs mobile, Exercise timer.

- To continually switch on and off an output i.e.
  warning lights, Bicycle indicators.

- As a pulse generator i.e.
  To provide a series of clock pulses for a counter.

Schematic Diagram of 555 Timer



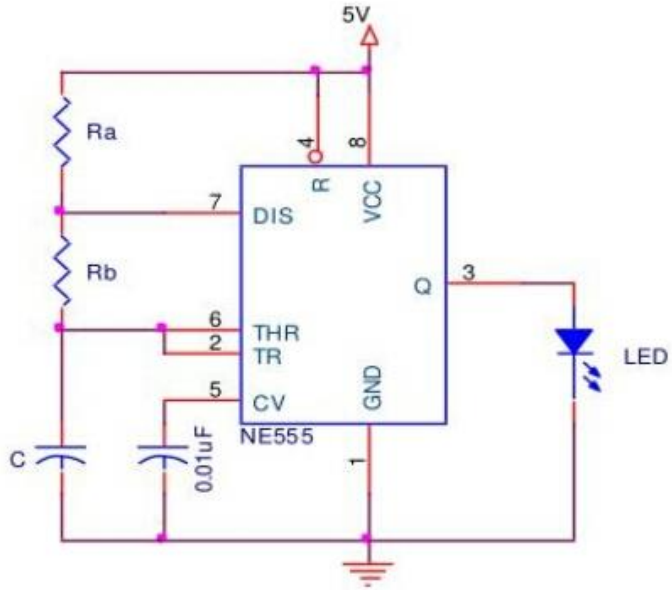
Supply voltage (V_{CC})	4.5 to 16 V
Supply current (V_{CC} = +5 V)	3 to 6 mA
Supply current (V_{CC} = +15 V)	10 to 15 mA
Output current (maximum)	200 mA
Maximum Power dissipation	600 mW
Power consumption (minimum operating)	30 mW @ 5V, 225 mW @ 15V
Operating temperature	0 to 70 °C

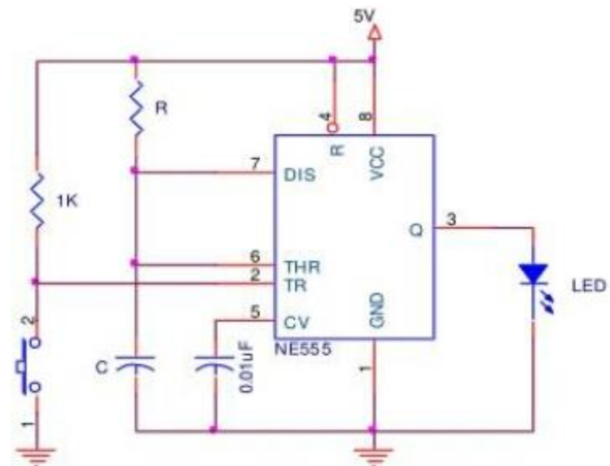
555 Timer operating modes

- The 555 has three operating modes:

    1. ***Monostable*** Multivibrator
    2. ***Astable*** Multivibrator
    3. ***Bistable*** Multivibratior

Types of 555-Timer Circuits

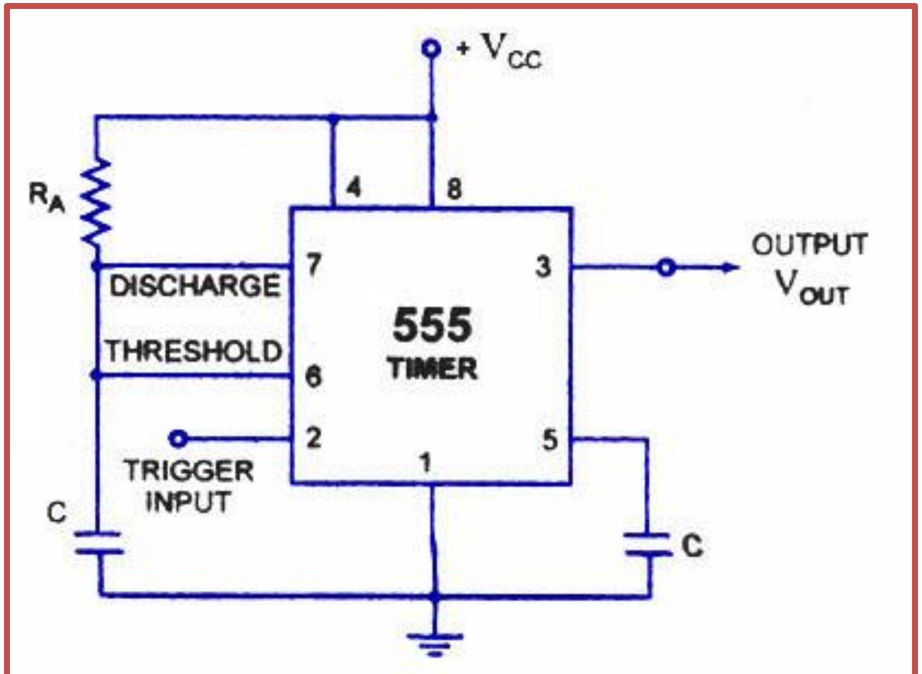




- Astable Multivibrator puts out a continuous sequence of pulses

- Monostable Multivibrator (or one-shot) puts out one pulse each time the switch is connected

555 Timer as Monostable Multivibrator



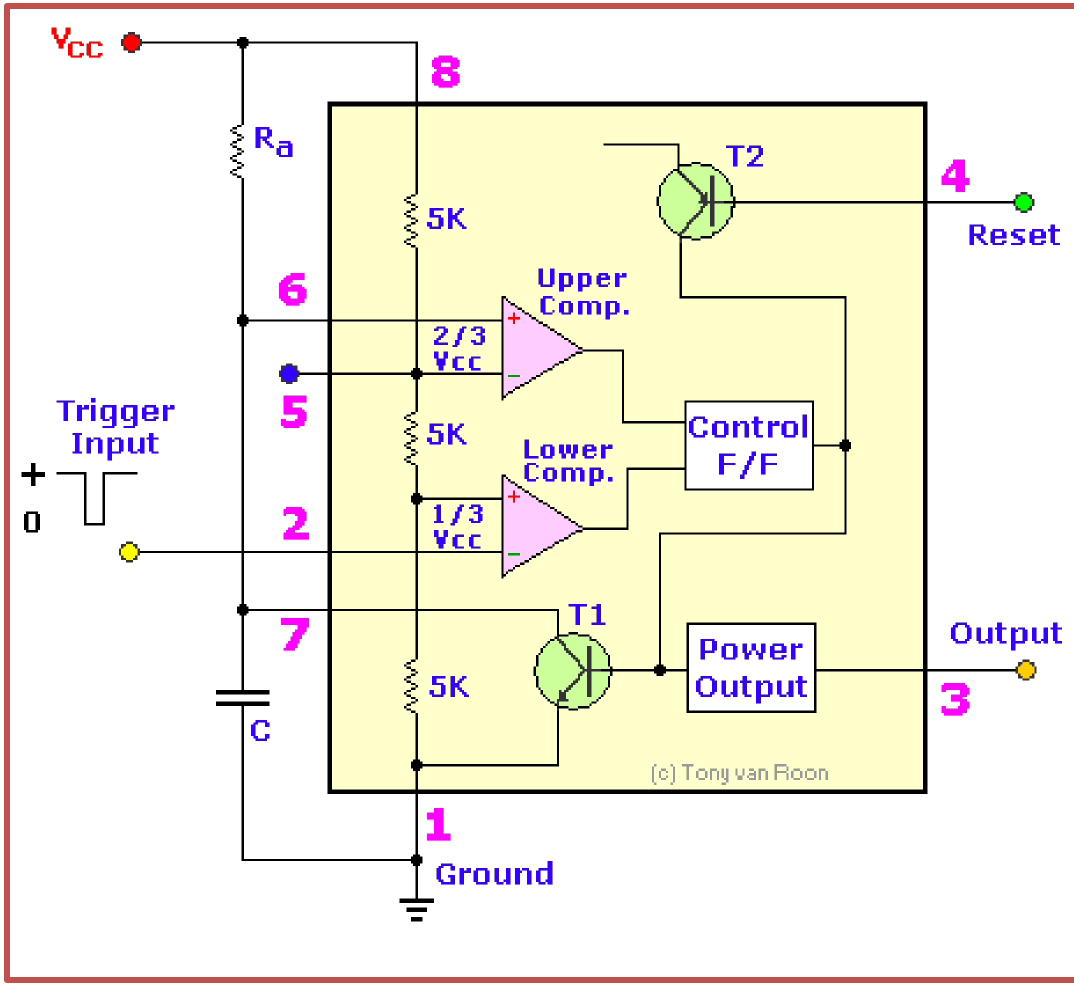
Circuit of The Timer 555 as a Monostable Multivibrator

Description:

- In the standby state, FF holds transistor Q_1 ON, thus clamping the external timing capacitor C to ground. The output remains at ground potential. i.e. Low.

- As the trigger passes through $V_{cc}/3$, the FF is set, i.e. Q bar=0, then the transistor Q_1 OFF and the short circuit across the timing capacitor C is released. As Q bar is low , output goes HIGH.

555 Timer as Monostable Multivibrator



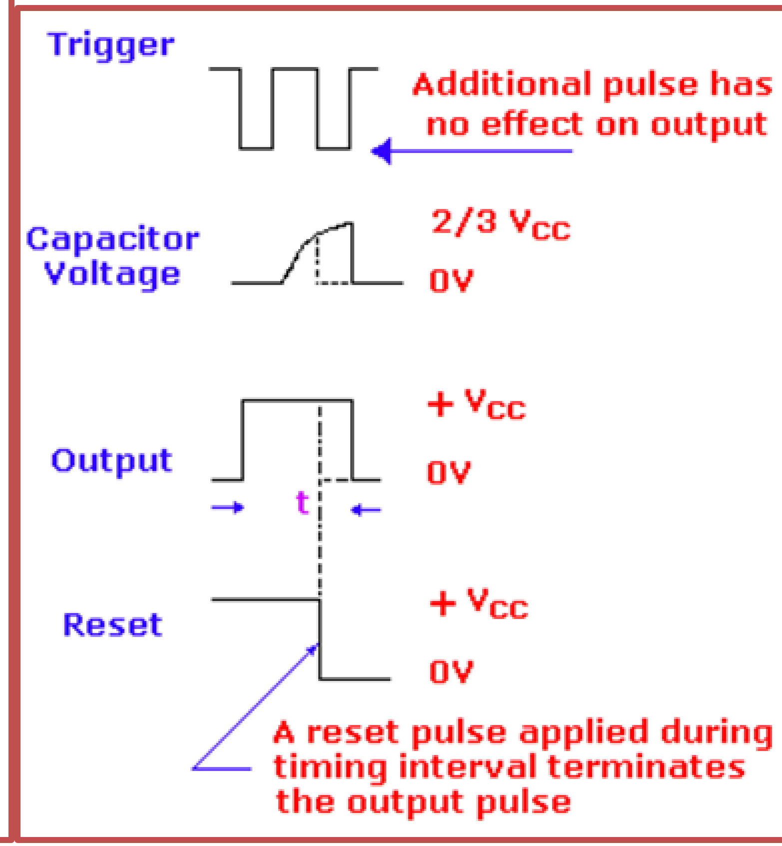
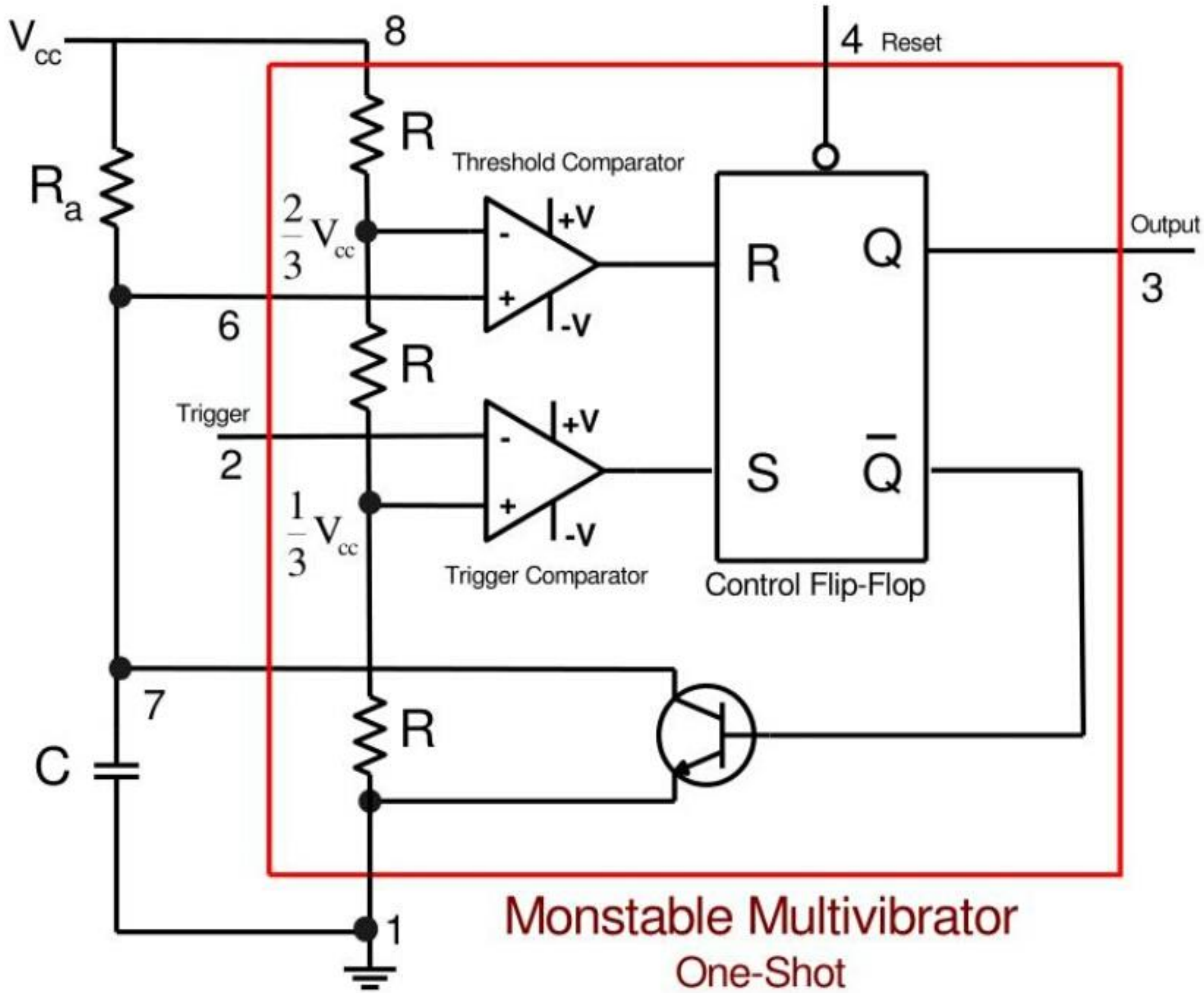


Fig (a): Timer in Monostable Operation with Functional Diagram
Fig (b): Output wave Form of Monostable

- Monostable Multivibrator (One Shot)



Monostable Multivibrator- Description

- Voltage across it rises exponentially through R towards V_{cc} with a time constant RC.
- After Time Period T, the capacitor voltage is just greater than $2V_{cc}/3$ and the upper comparator resets the FF, i.e. R=1, S=0. This makes Q bar =1, C rapidly to ground potential.
- The voltage across the capacitor as given by,

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

at $t = T, v_C = \frac{2}{3}V_{CC}$

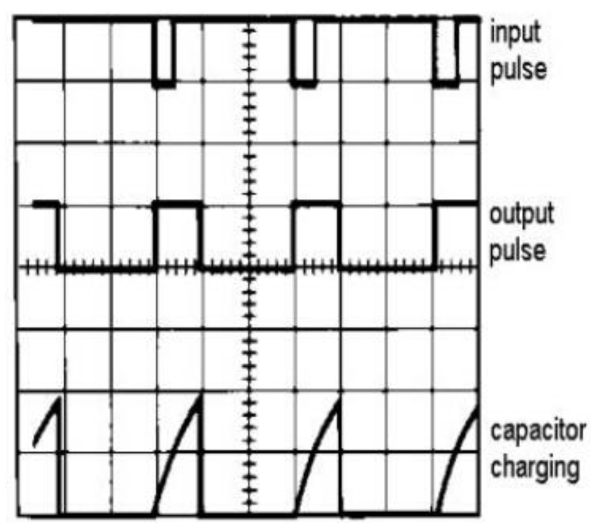
$$\frac{2}{3}V_{CC} = V_{CC}(1 - e^{-T/RC})$$

$$T = RC\ln(\frac{1}{3}) \Rightarrow T = 1.1RC\sec$$

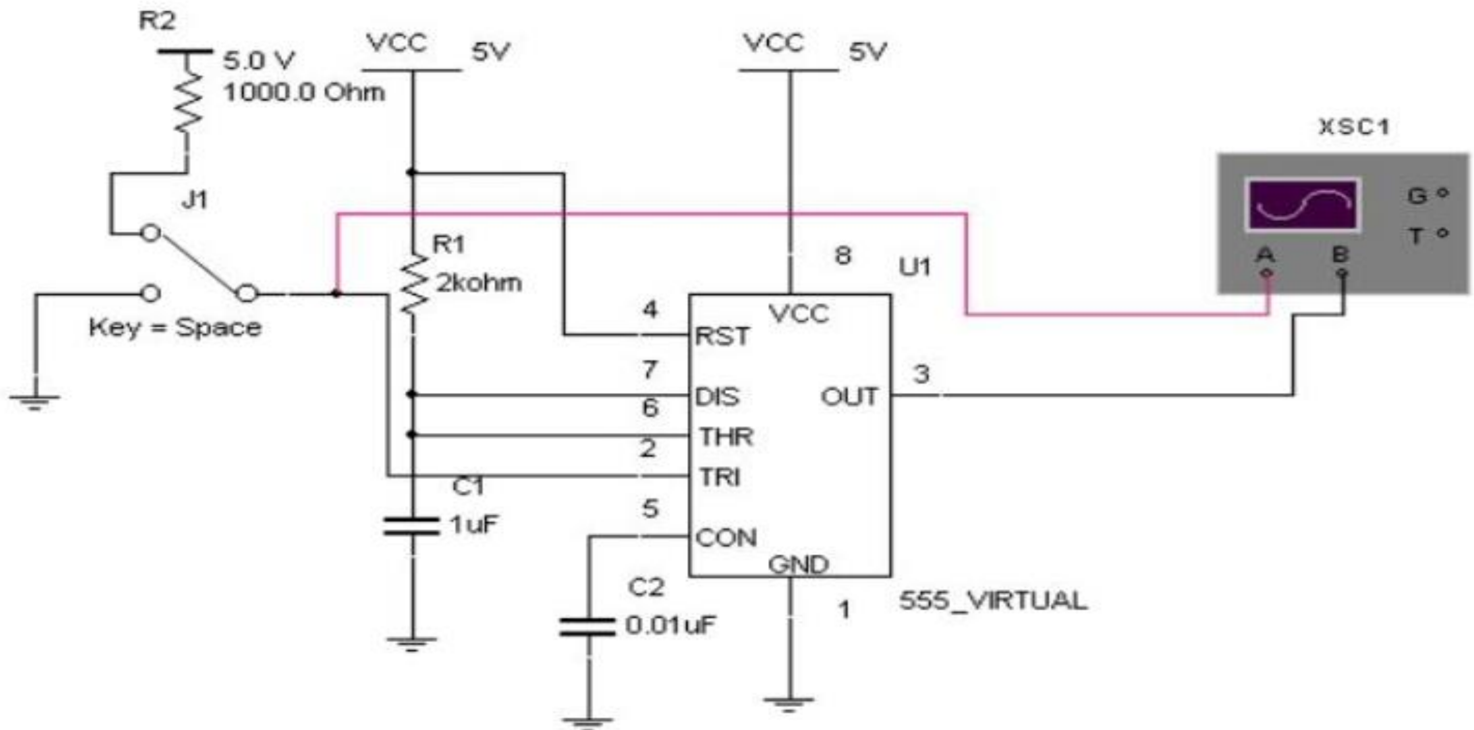
➢ If –ve going reset pulse terminal (pin 4) is applied, then transistor Q_2-> OFF, Q_1-> ON & the external timing capacitor C is immediately discharged.

Behavior of the Monostable Multivibrator

- The monostable multivibrator is constructed by adding an external capacitor and resistor to a 555 timer.
- The circuit generates a single pulse of desired duration when it receives a trigger signal, hence it is also called a one-shot.
- The time constant of the resistor-capacitor combination determines the length of the pulse.



555 Timer as a One Shot



$$t_w = 1.1R1C1 = 1.1(2000\Omega)(1\mu F) = 2.2ms$$

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Uses of the Monostable Multivibrator

- Used to generate a clean pulse of the correct height and duration for a digital system
- Used to turn circuits or external components on or off for a specific length of time.
- Used to generate delays.
- Can be cascaded to create a variety of sequential timing pulses. These pulses can allow you to time and sequence a number of related operations.

Monostable Multivibrator

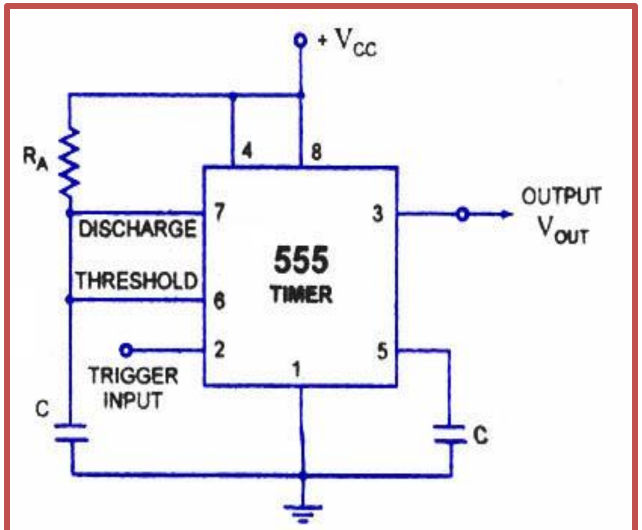
Problem:

In the monostable multivibrator of fig, R=100kΩ and the time delay T=100ms. Calculate the value of C ?

Solution:

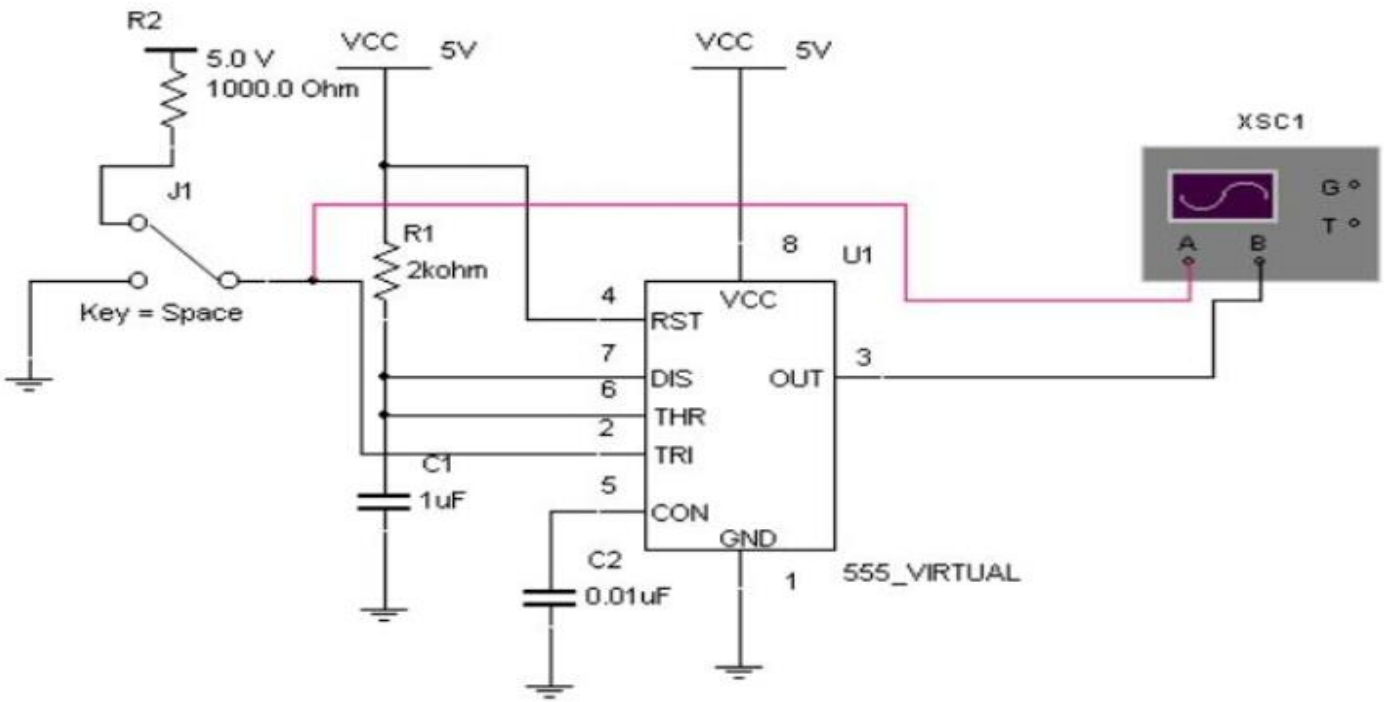
T=1.1RC

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



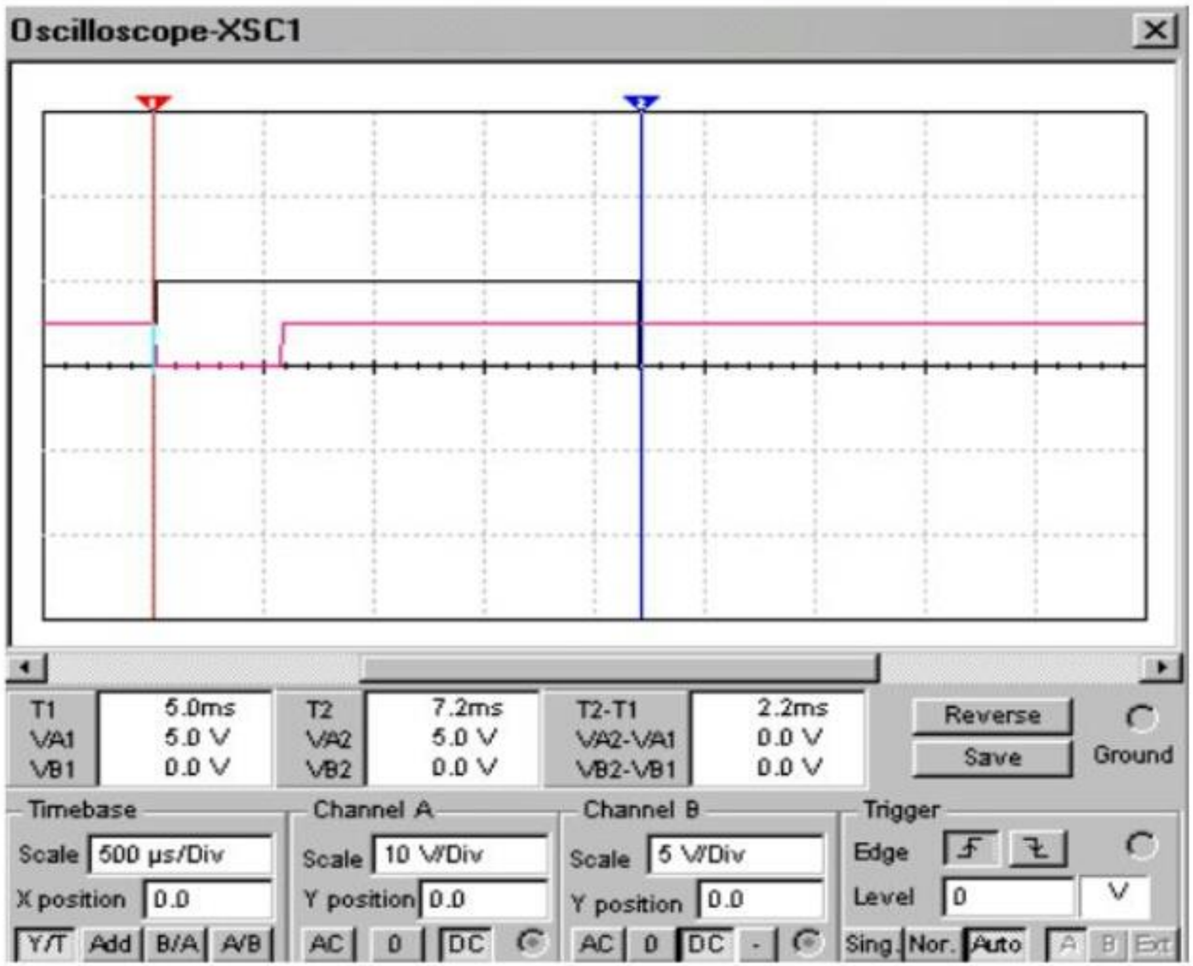
Circuit of The Timer 555 as a Monostable Multivibrator

555 Timer as a One Shot

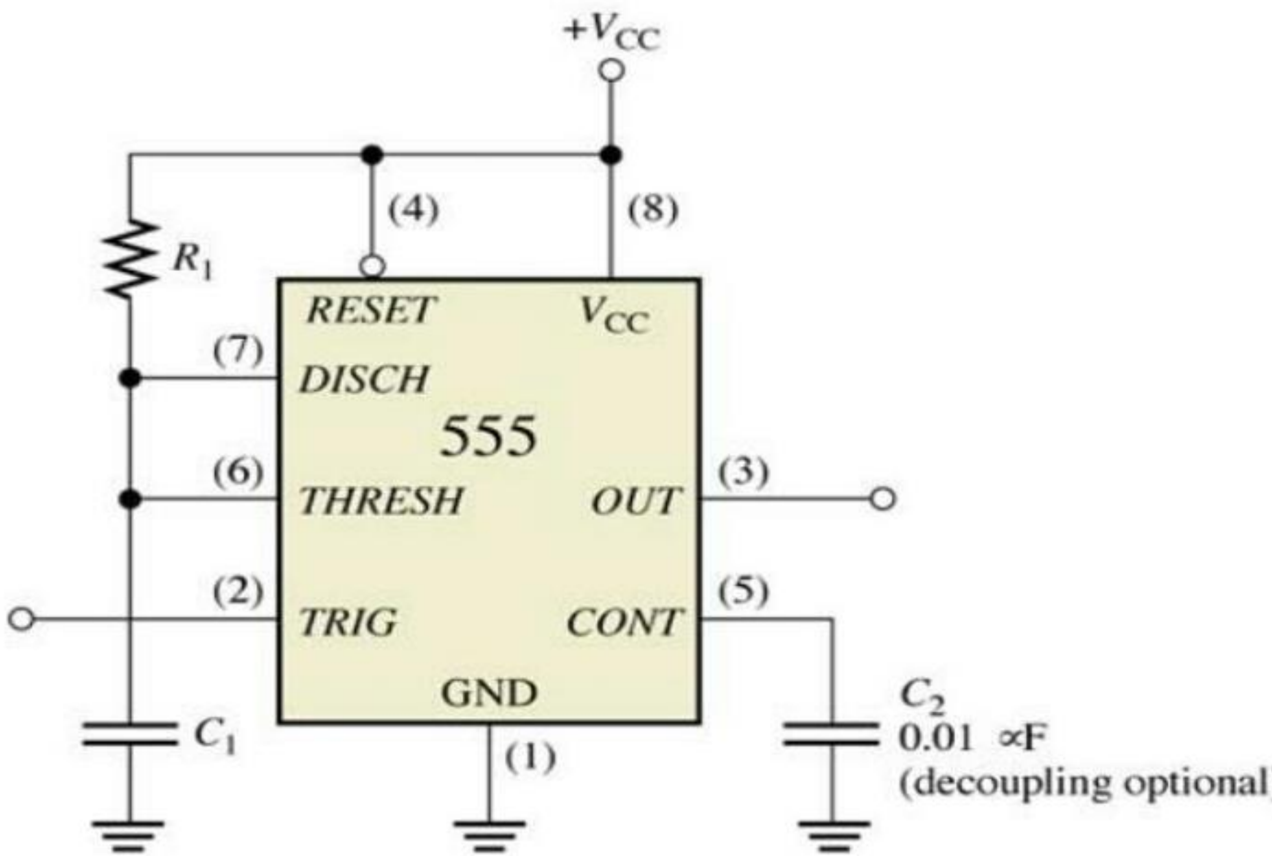


$$t_w = 1.1R1C1 = 1.1(2000\Omega)(1\mu F) = 2.2ms$$

555 Timer as a One Shot waveform



The 555 Timer Connected as a One-shot. Figure 8--49



Applications in Monostable Mode

1. Missing Pulse Detector.
2. Linear Ramp Generator.
3. Frequency Divider.
4. Pulse Width Modulation.

Uses of the Monostable Multivibrator

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- Used to turn circuits or external components on or off for a specific length of time.
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1.Missing Pulse Detector

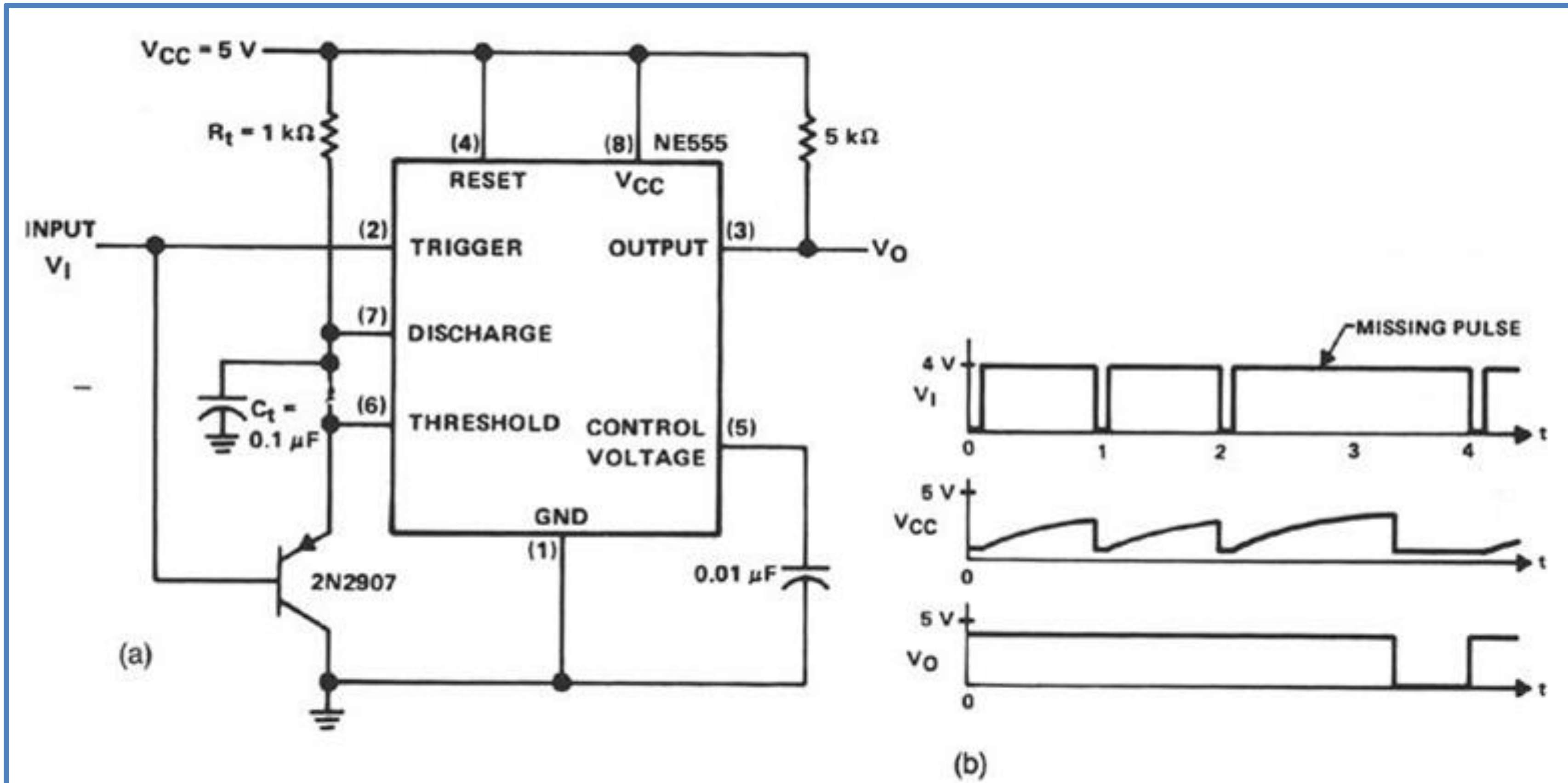


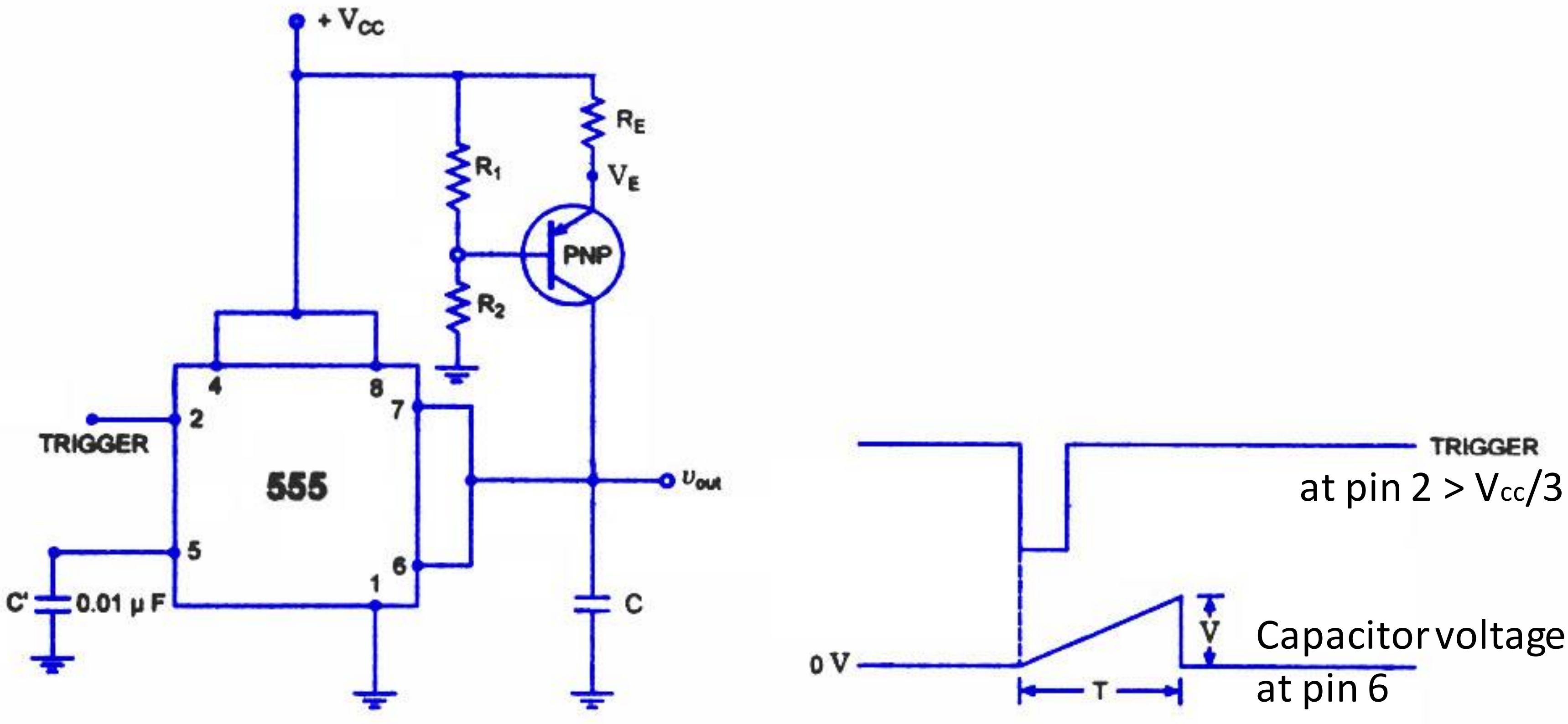
Fig (a) : A missing Pulse Detector Monostable Circuit

Fig (b) : Output of Missing Pulse Detector

Missing Pulse Detector- Description

- When input trigger is Low, emitter-base diode of Q is forwarded biased capacitor is clamped to 0.7v(of diode), output of timer is HIGH width of T o/p of timer > trigger pulse width.
- T=1.1RC select R & C such that T > trigger pulse.
- Output will be high during successive coming of input trigger pulse. If one of the input trigger pulse missing trigger i/p is HIGH, Q is cut off, timer acts as normal monostable state.
- It can be used for speed control and measurement.

2.Linear Ramp Generator



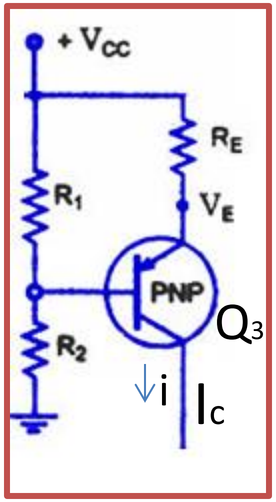
Circuit

Trigger and Ramp Waveforms

Ramp Generator Using The Timer 555

Linear Ramp Generator- Description

Analysis:



Applying KVL around base-emitter loop of Q_3

$$\frac{R_1}{R_1+R_2}V_{CC}-V_{BE}=I_E R_E=(I_C+I_B)R_E=(I_B\beta+I_B)R_E=(1+\beta)I_B R_E=\beta I_B R_E\approx I_C R_E=i\,R_E$$

$$(\because I_C=i)$$

$$i\,R_E=\frac{R_1V_{CC}-V_{BE}(R_1+R_2)}{R_1+R_2}\Rightarrow i=\frac{R_1V_{CC}-V_{BE}(R_1+R_2)}{R_E(R_1+R_2)}$$

Voltage Capacitor,

$$v_c=\frac{1}{C}\int_0^t idt=\frac{1}{C}\int_0^t\{\frac{R_1V_{CC}-V_{BE}(R_1+R_2)}{R_E(R_1+R_2)}\}dt=\frac{1}{C}\{\frac{R_1V_{CC}-V_{BE}(R_1+R_2)}{R_E(R_1+R_2)}\}t$$

When v_c becomes $\frac{2}{3}V_{CC}$ at T,

$$\frac{2}{3}V_{CC}=\frac{R_1V_{CC}-V_{BE}(R_1+R_2)}{CR_E(R_1+R_2)}T\quad\Rightarrow\quad\therefore T=\frac{\frac{2}{3}V_{CC}CR_E(R_1+R_2)}{R_1V_{CC}-V_{BE}(R_1+R_2)}$$

3.Frequency Divider

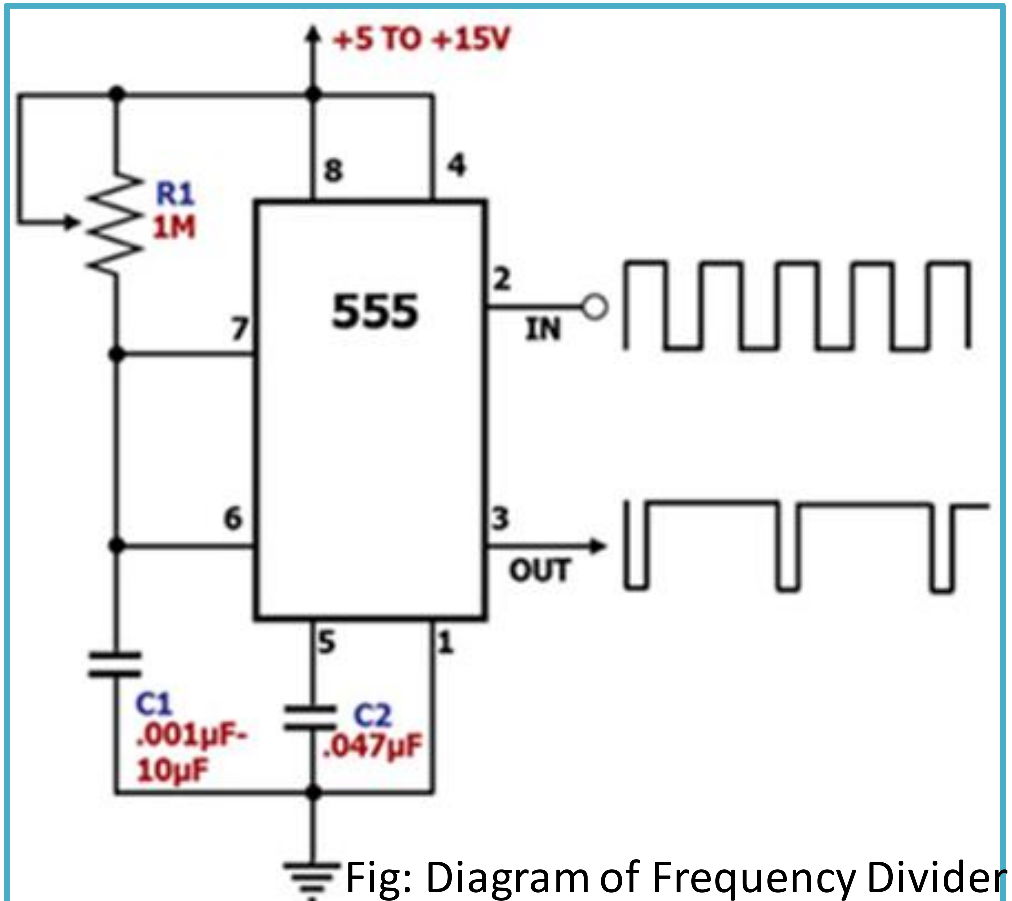


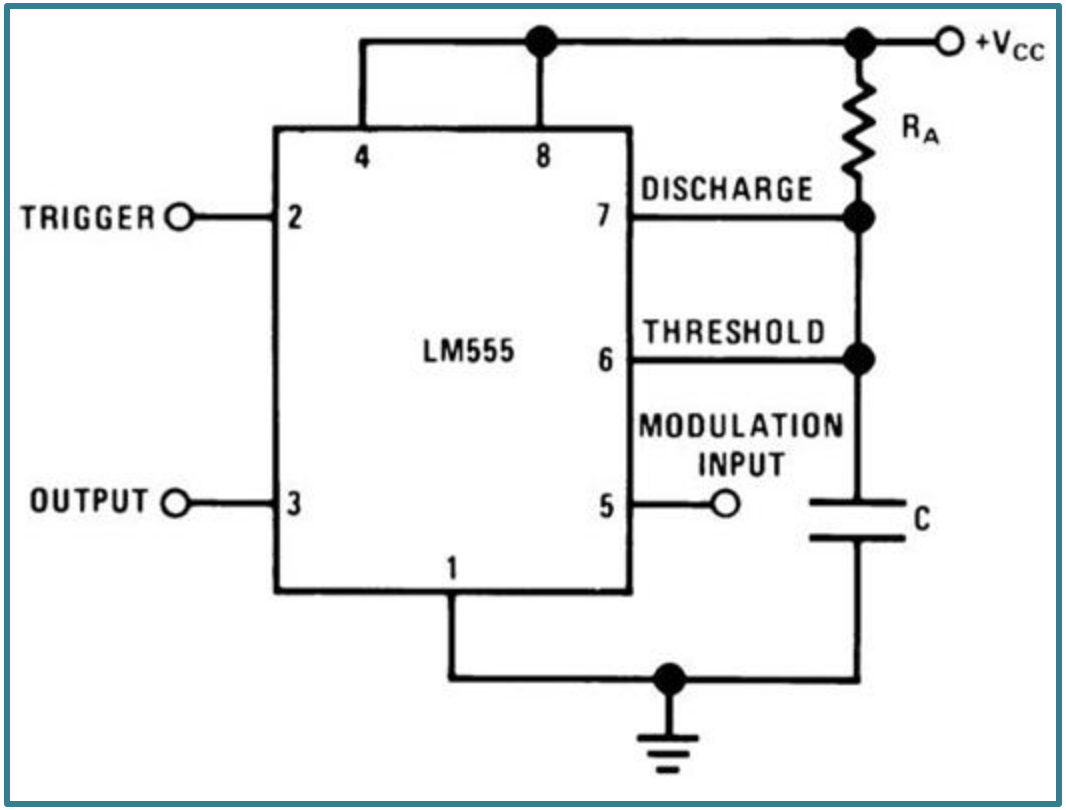
Fig: Diagram of Frequency Divider

Description:

A continuously triggered monostable circuit when triggered by a square wave generator can be used as a frequency divider, if the timing interval is adjusted to be longer than the period of the triggering square wave input signal.

The monostable multivibrator will be triggered by the first negative going edge of the square wave input but the output will remain HIGH(because of greater timing interval) for next negative going edge of the input square wave as shown fig.

4.Pulse Width Modulation



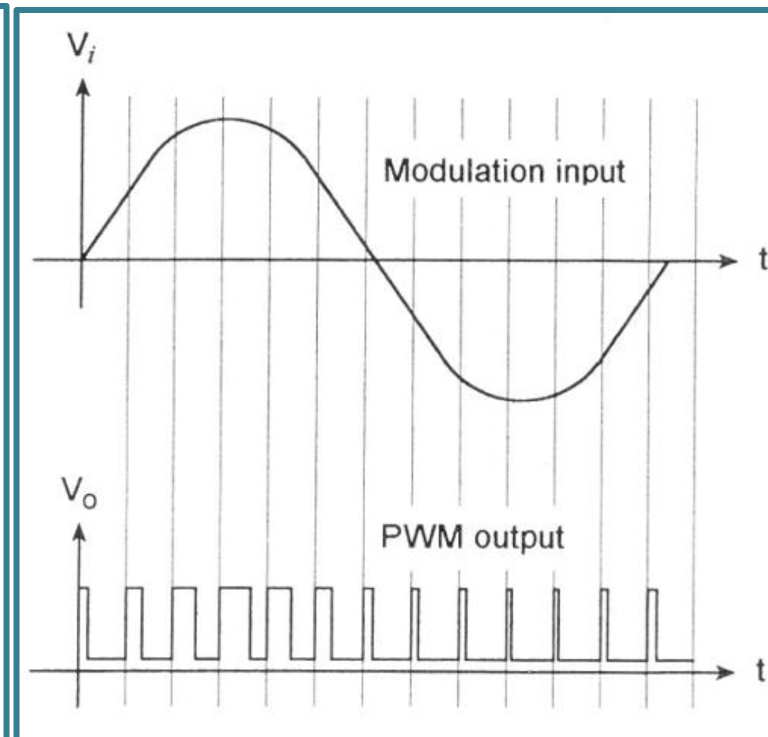


Fig a: Pulse Width Modulation

Fig b: PWM Wave Forms

Pulse Width Modulation- Description

The charging time of capacitor is entirely depend upon $2V_{cc}/3$. When capacitor voltage just reaches about $2V_{cc}/3$ output of the timer is coming from HIGH to Low level.

We can control this charging time of the capacitor by adding continuously varying signal at the pin-5 of the 555 timer which is denoted as control voltage point. Now each time the capacitor voltage is compared control voltage according to the o/p pulse width change. So o/p pulse width is changing according to the signal applied to control voltage point. So the output is pulse width modulated form.

Pulse Width Modulation

Practical Representation

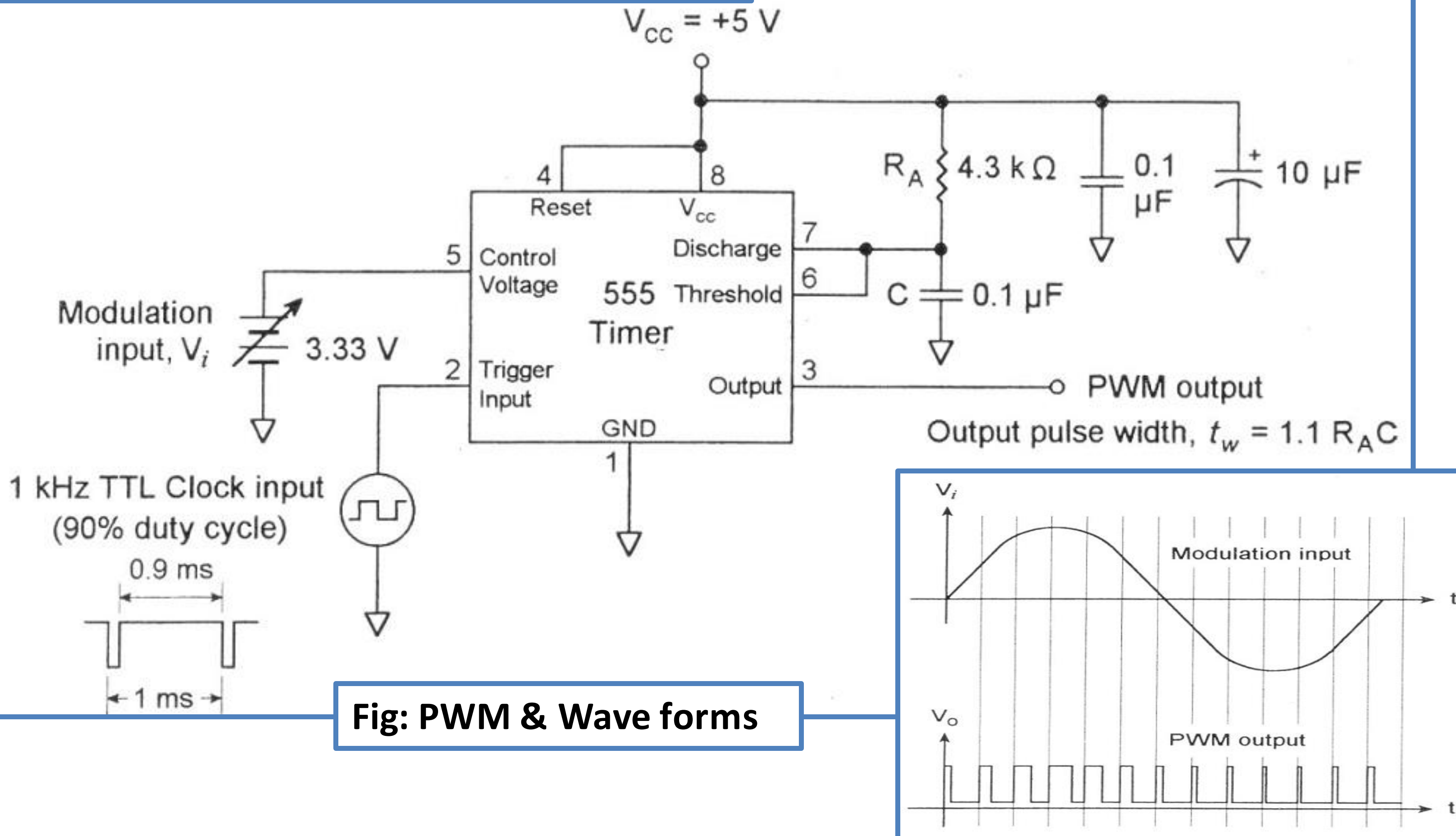
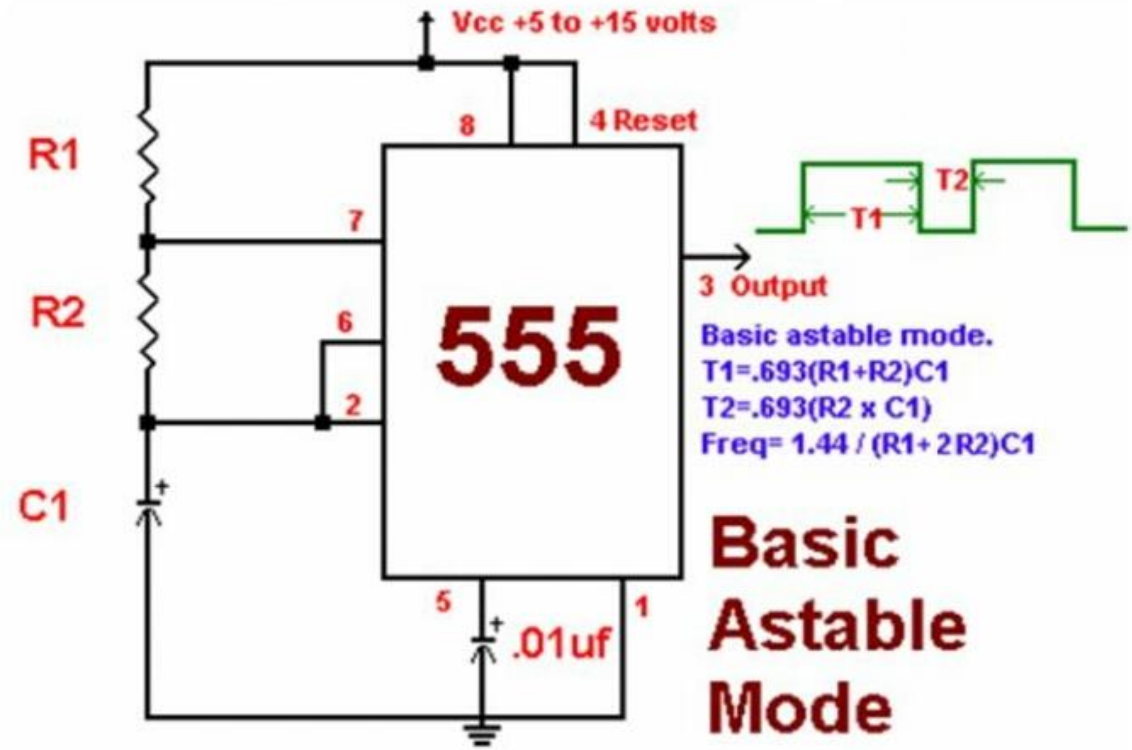


Fig: PWM & Wave forms

Astable Multi Vibrator

Understanding the Astable Mode Circuit



- 555-Timers, like op-amps can be configured in different ways to create different circuits. We will now look into how this one creates a train of equal pulses, as shown at the output.

Astable Multivibrator

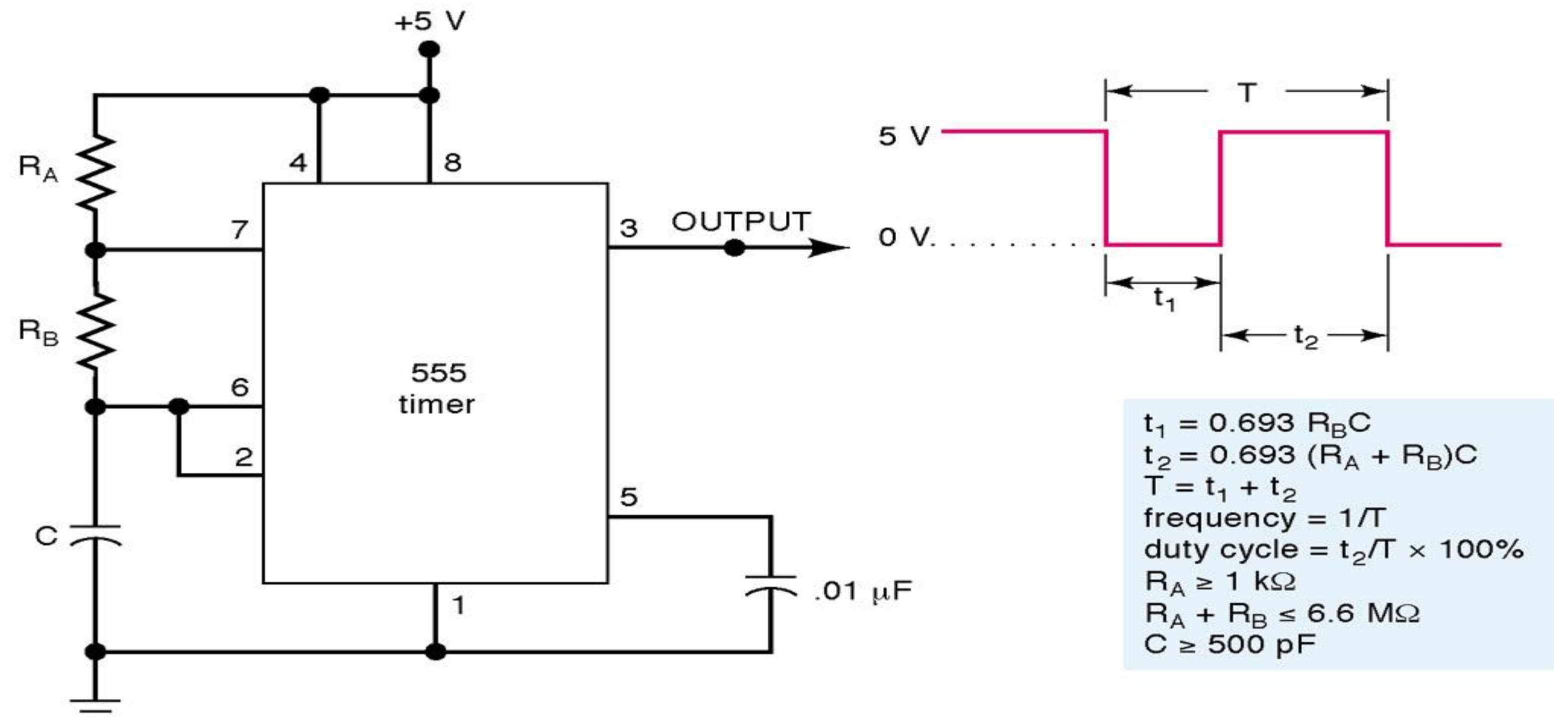


Fig (a): Diagram of Astable Multvibrator

1 – Ground
2 – Trigger
3 – Output
4 – Reset (Set HIGH for normal operation)
5 – FM Input (Tie to gnd via bypass cap)
6 – Threshold
7 – Discharge
8 – Voltage Supply (+5 to +15 V)

Astable Multivibrator

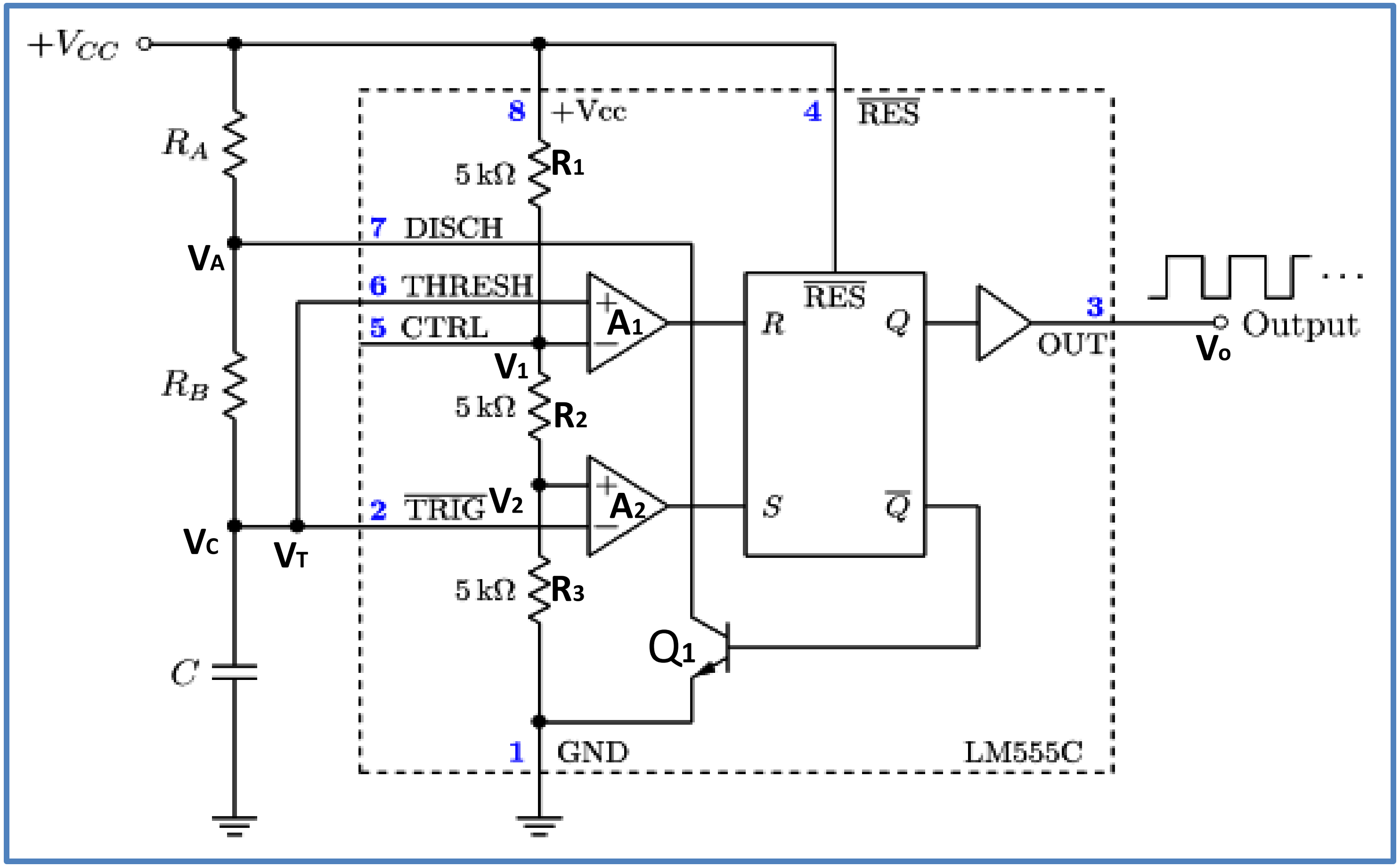


Fig (b): Functional Diagram of Astable Multivibrator using 555 Timer

Astable Multivibrator- Description

- Connect external timing capacitor between trigger point (pin 2) and Ground.
- Split external timing resistor R into R_A & R_B, and connect their junction to discharge terminal (pin 7).
- Remove trigger input, monostable is converted to Astable multivibrator.
- This circuit has no stable state. The circuits changes its state alternately. Hence the operation is also called free running oscillator.

Astable 555 Timer Block Diagram Contents

- Resistive voltage divider (equal resistors) sets threshold voltages for comparators

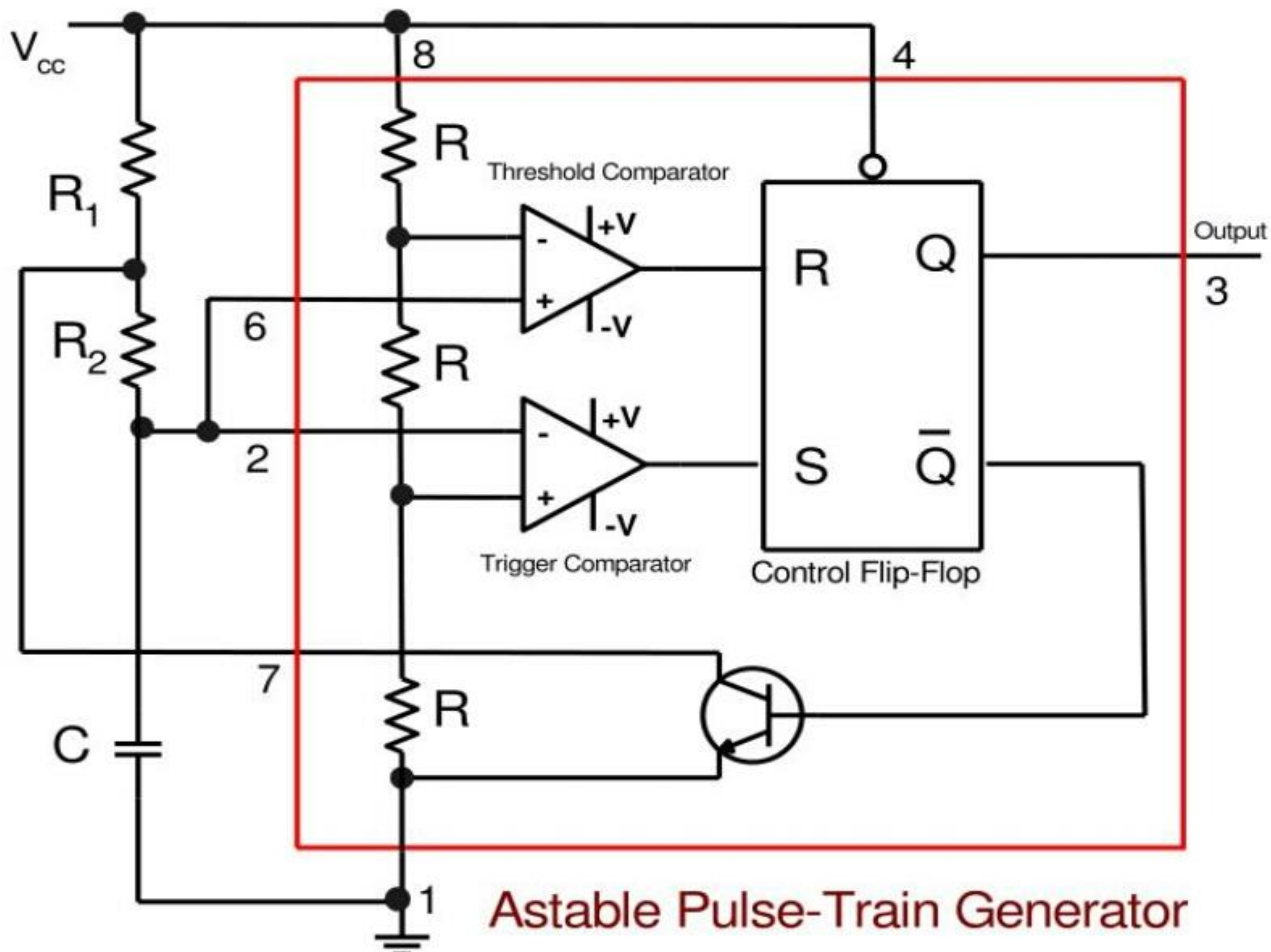
  $V_1 = V_{TH} = 2/3\ V_{CC}$ $V_2 = V_{TL} = 1/3\ V_{CC}$

- Two Voltage Comparators
  - For A_1, if $V_+ > V_{TH}$ then R =HIGH
  - For A_2, if $V_- < V_{TL}$ then S = HIGH

- RS FF
  - If S = HIGH, then FF is SET, $\overline{Q}$= LOW, Q_1 OFF, V_{OUT} = HIGH
  - If R = HIGH, then FF is RESET, $\overline{Q}$= HIGH, Q_1 ON, V_{OUT} = LOW

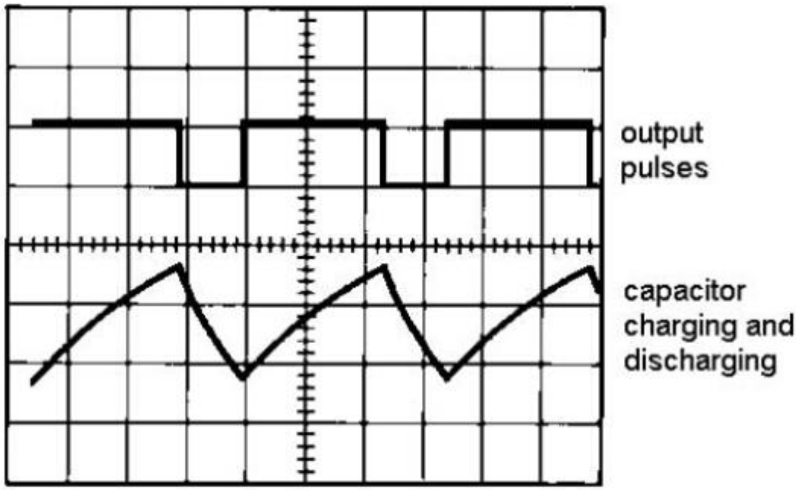
- Transistor Q_1 is used as a Switch

Astable Pulse-Train Generator (Multivibrator)



Behavior of the Astable Multivibrator

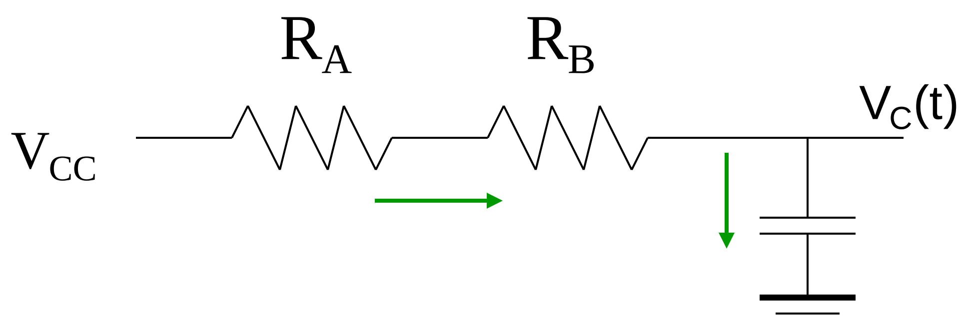
- The astable multivibrator is simply an oscillator. The astable multivibrator generates a continuous stream of rectangular off-or pulses that switch between two voltage levels.
- The frequency of the pulses and their duty cycle are dependent upon the RC network values.
- The capacitor C charges through the series resistors R_1 and R_2 with a time constant $(R_1 + R_2)C$.
- The capacitor discharges through R_2 with a time constant of R_2C



Operation of a 555 Astable

1) Assume initially that the capacitor is discharged.
   a) For A1, $V_+ = V_C = 0V$ and for A2, $V_- = V_C = 0V$, so R=LOW, S=HIGH, $\overline{Q}$ = LOW , Q1 OFF, $V_{OUT} = V_{CC}$
   b) Now as the capacitor charges through R_A & R_B, eventually $V_C > V_{TL}$ so R=LOW & S=LOW.

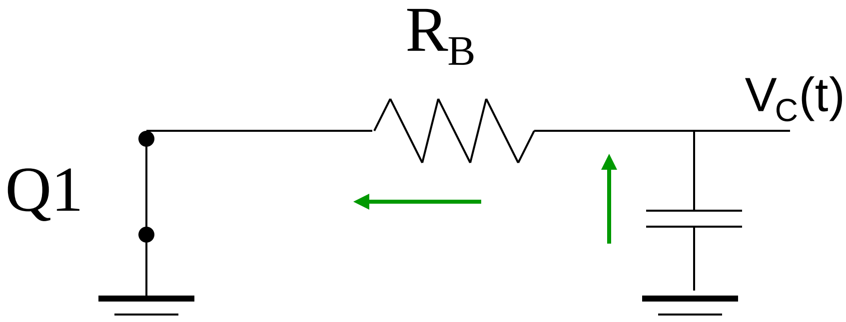
      FF does not change state.



Operation of a 555 Astable

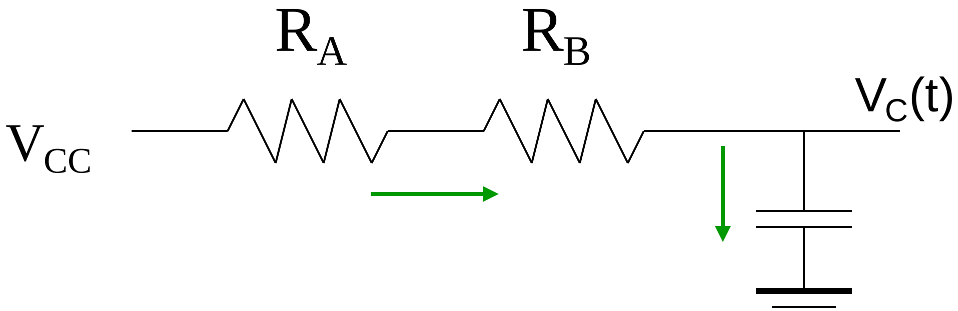
Continued……

2) Once $V_C \geq V_{TH}$
   a) R=HIGH, S=LOW, $\overline{Q}$ = HIGH ,Q1 ON, V_{OUT} = 0
   b) Capacitor is now discharging through R_B and Q_1 to ground.
   c) Meanwhile at FF, R=LOW & S=LOW since $V_C < V_{TH}$.

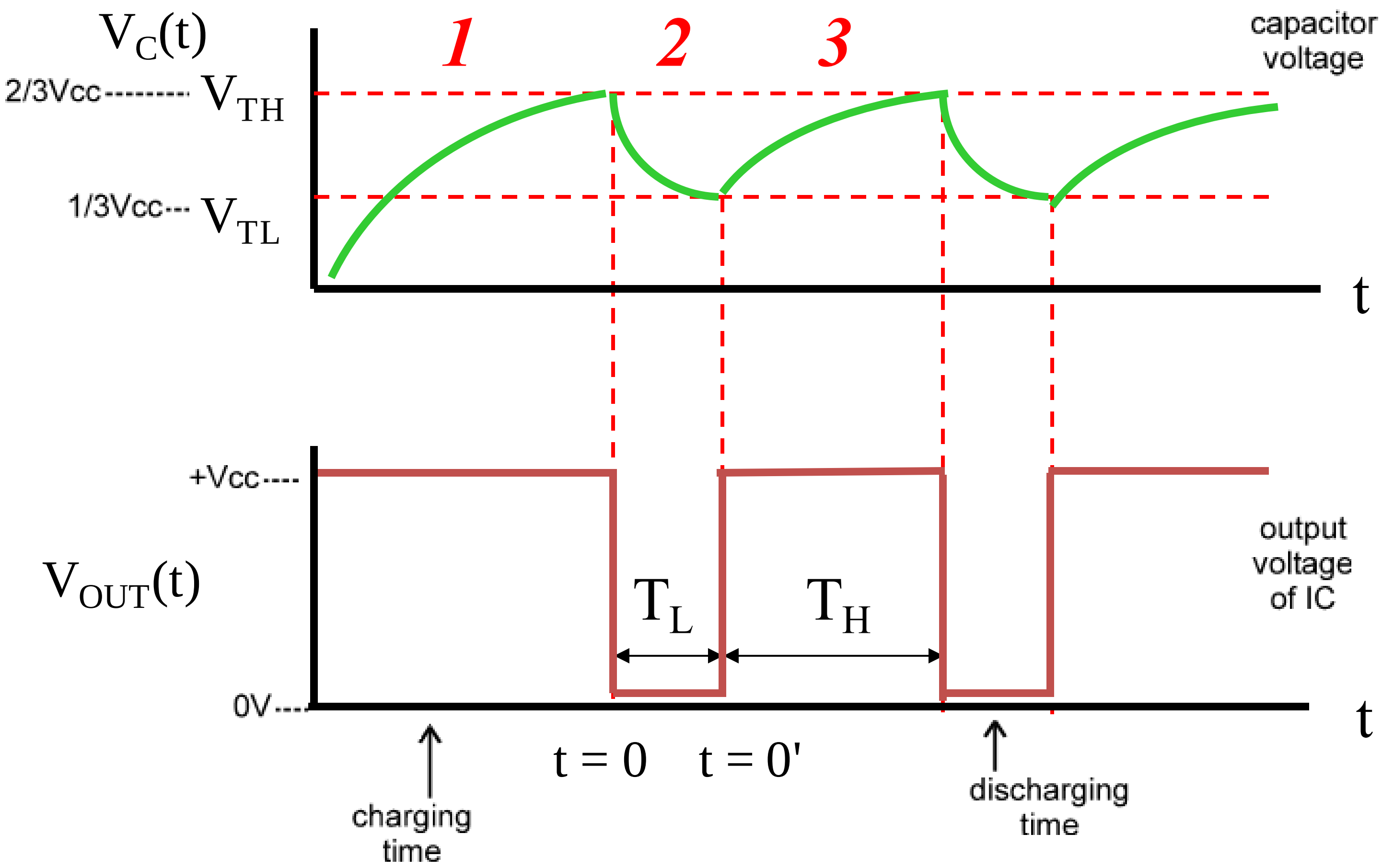


Operation of a 555 Astable
Continued.....

3) Once $V_C < V_{TL}$
   a) R=LOW, S=HIGH, $\bar{Q}$= LOW , Q1 OFF, $V_{OUT} = V_{CC}$
   b) Capacitor is now charging through R_A & R_B again.



Timing Diagram of a 555 Astable



Astable Multivibrator- Analysis

The capacitor voltage for a low pass RC circuit subjected to a step 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, $V_C = \frac{2}{3}V_{CC}$

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

The time t_2 to charge from 0 to $v_{cc}/3$ is $V_C = \frac{1}{3}V_{CC}$

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

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, $t_{HIGH} = 0.69(R_A + R_B)C$ …… Charging time

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

Contd….

Astable Multivibrator- Analysis

After solving, we get, t=0.69RC

For the given circuit, $t_{LOW} = 0.69\, R_B C$ …… Discharging time

Both R_A and R_B are in the charge path, but only R_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, $f = \dfrac{1}{T} = \dfrac{1}{0.69\,(R_A + 2R_B)C} = \dfrac{1.45}{(R_A + 2R_B)C}$ …….1.45 is Error Constant

Duty Cycle,

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

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

Behavior of the Astable Multivibrator

- The astable multivibrator is simply an oscillator. The astable multivibrator generates a continuous stream of rectangular off-on pulses that switch between two voltage levels.
- The frequency of the pulses and their duty cycle are dependent upon the RC network values.
- The capacitor C charges through the series resistors R_A and R_B with a time constant $(R_A + R_B)C$.
- The capacitor discharges through R_B with a time constant of R_BC

Uses of the Astable Multivibrator

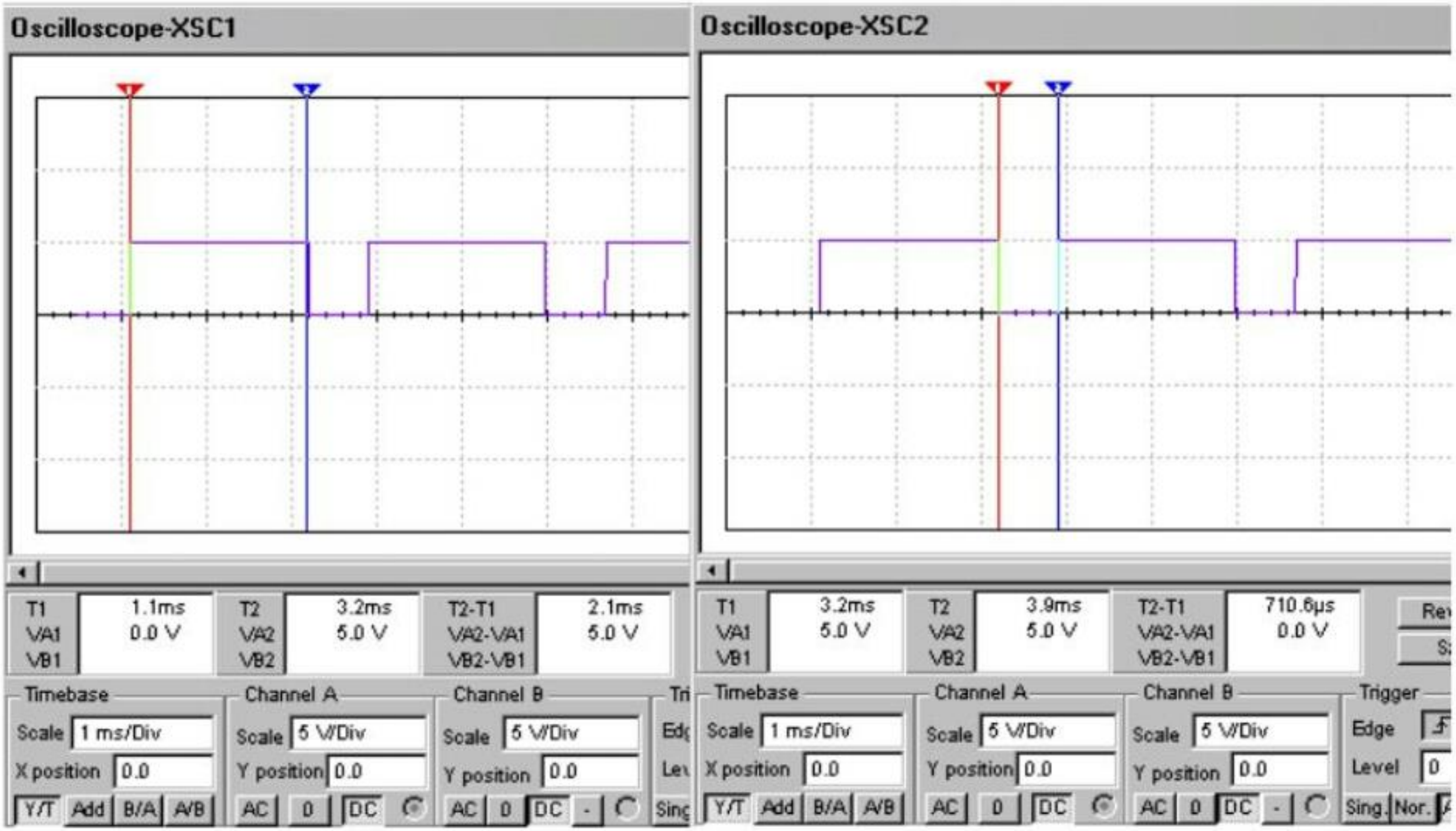
- Flashing LED's
- Pulse Width Modulation PWM
- Pulse Position Modulation PPM
- Periodic Timers
- Uses include Blinking LEDs,

  pulse generation,

  Logic clocks,

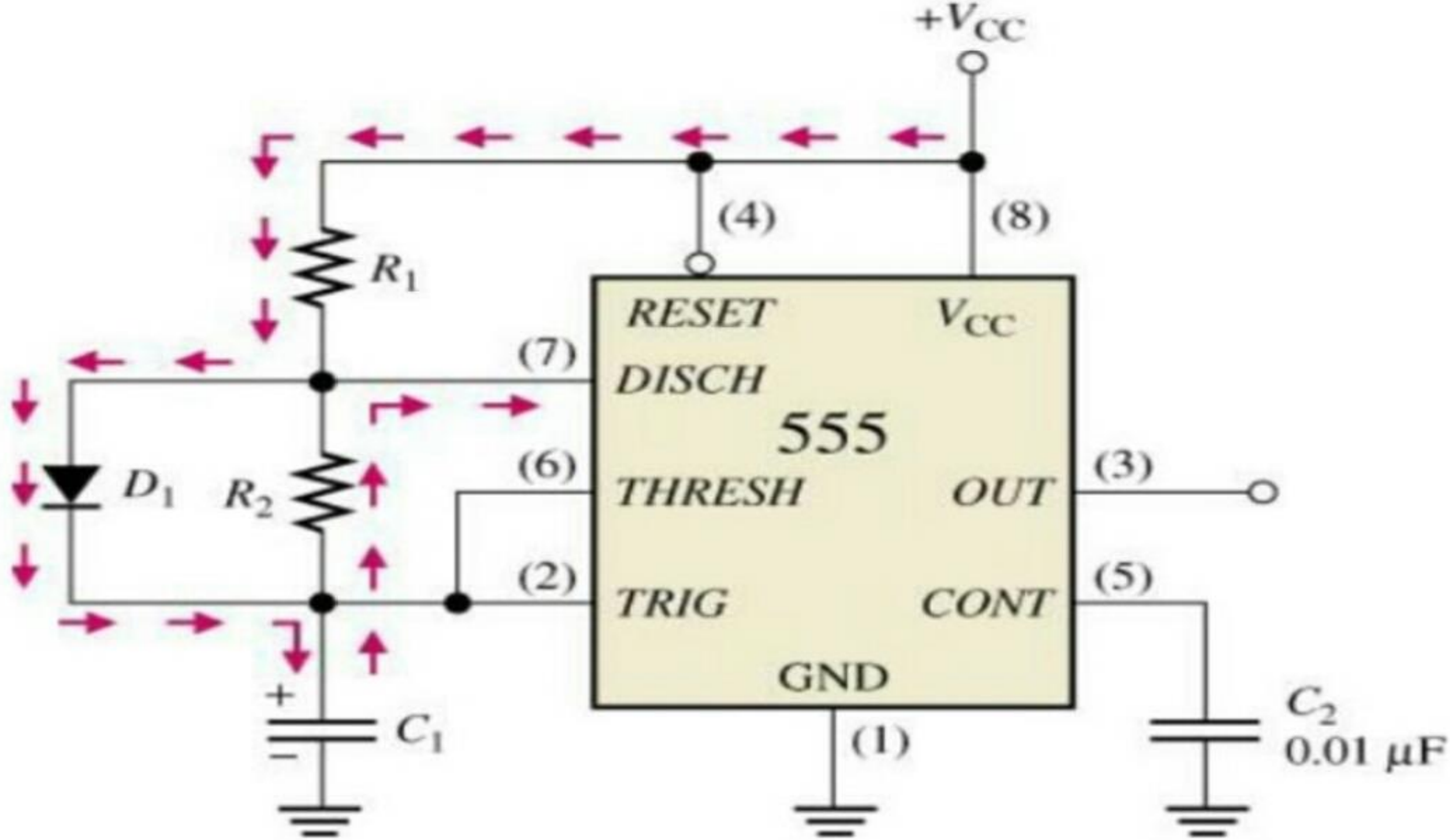
  Security alarms and so on.

Astable operation of 555 Timer waveform

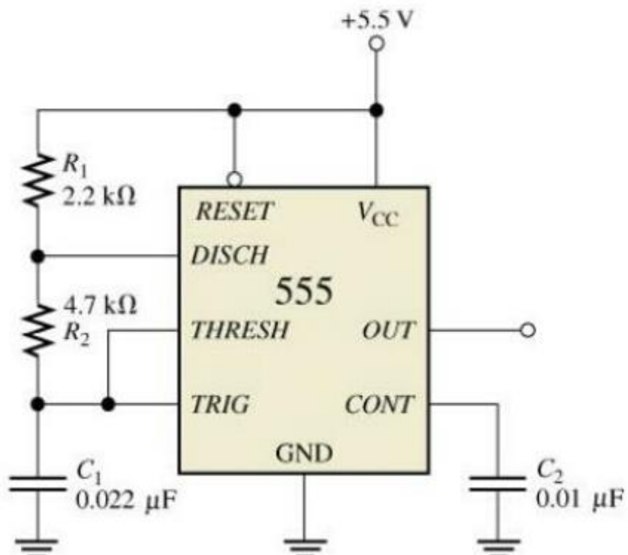


C.R.O. Output

Less than 50% Duty Cycle



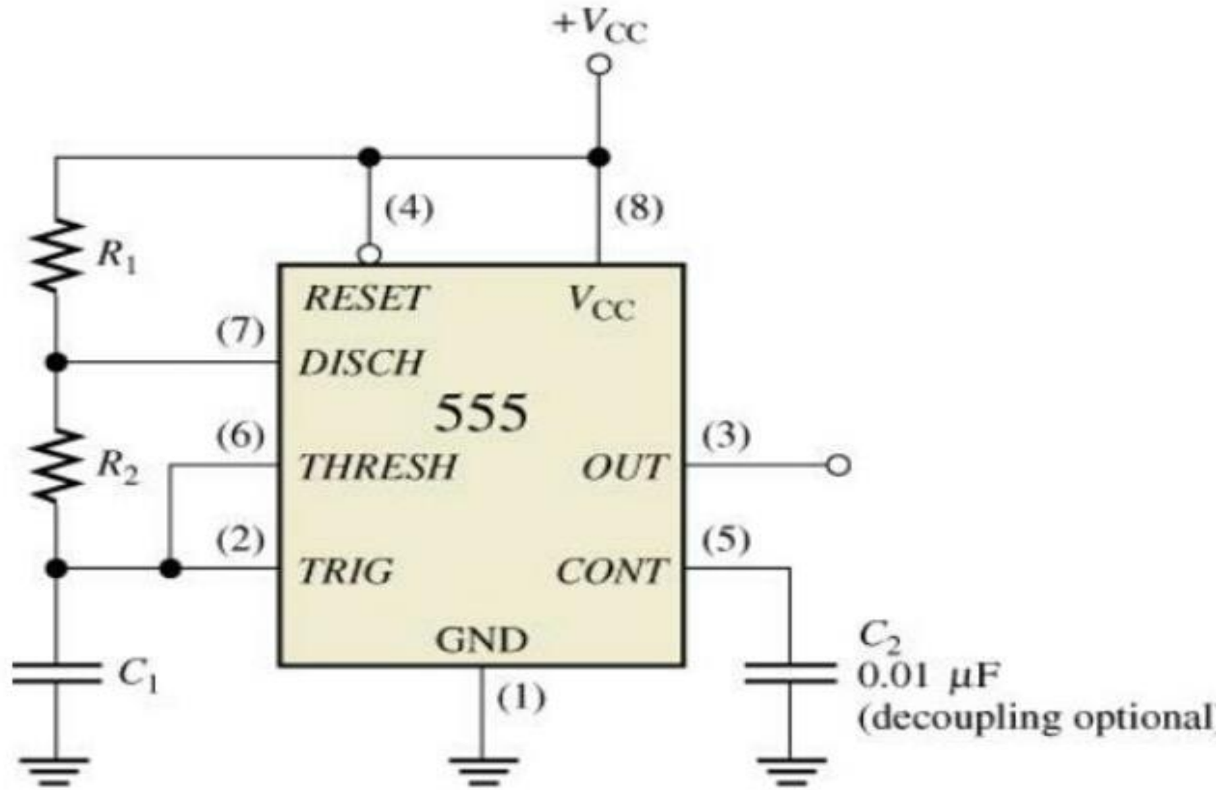
Example 8-14. Figure 8--55



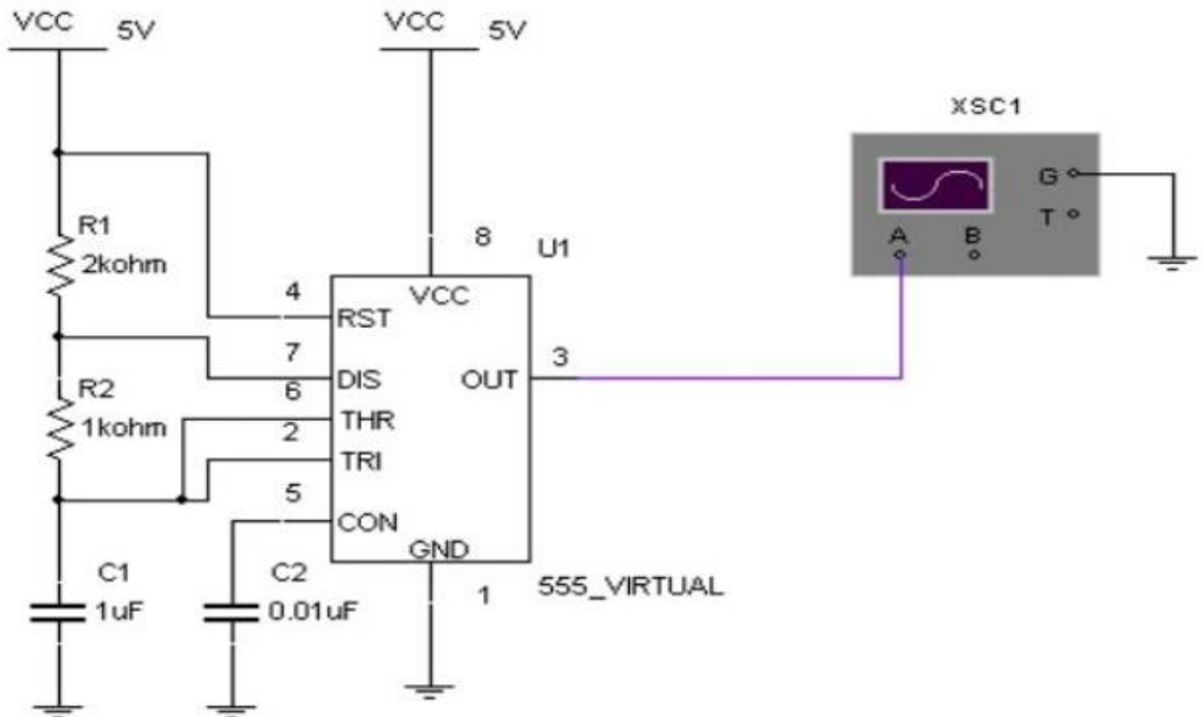
$$f = \frac{1.44}{(R_1 + 2R_2)C_1} = \frac{1.44}{(2.2k\Omega + 9.4k\Omega)0.022\mu F} = 5.64kHz$$

$$DutyCycle = \left(\frac{R_1 + R_2}{R_1 + 2R_2}\right)100\% = \left(\frac{2.2k\Omega + 4.7k\Omega}{2.2k\Omega + 9.4k\Omega}\right)100\% = 59.5\%$$

Astable operation of 555 Timer

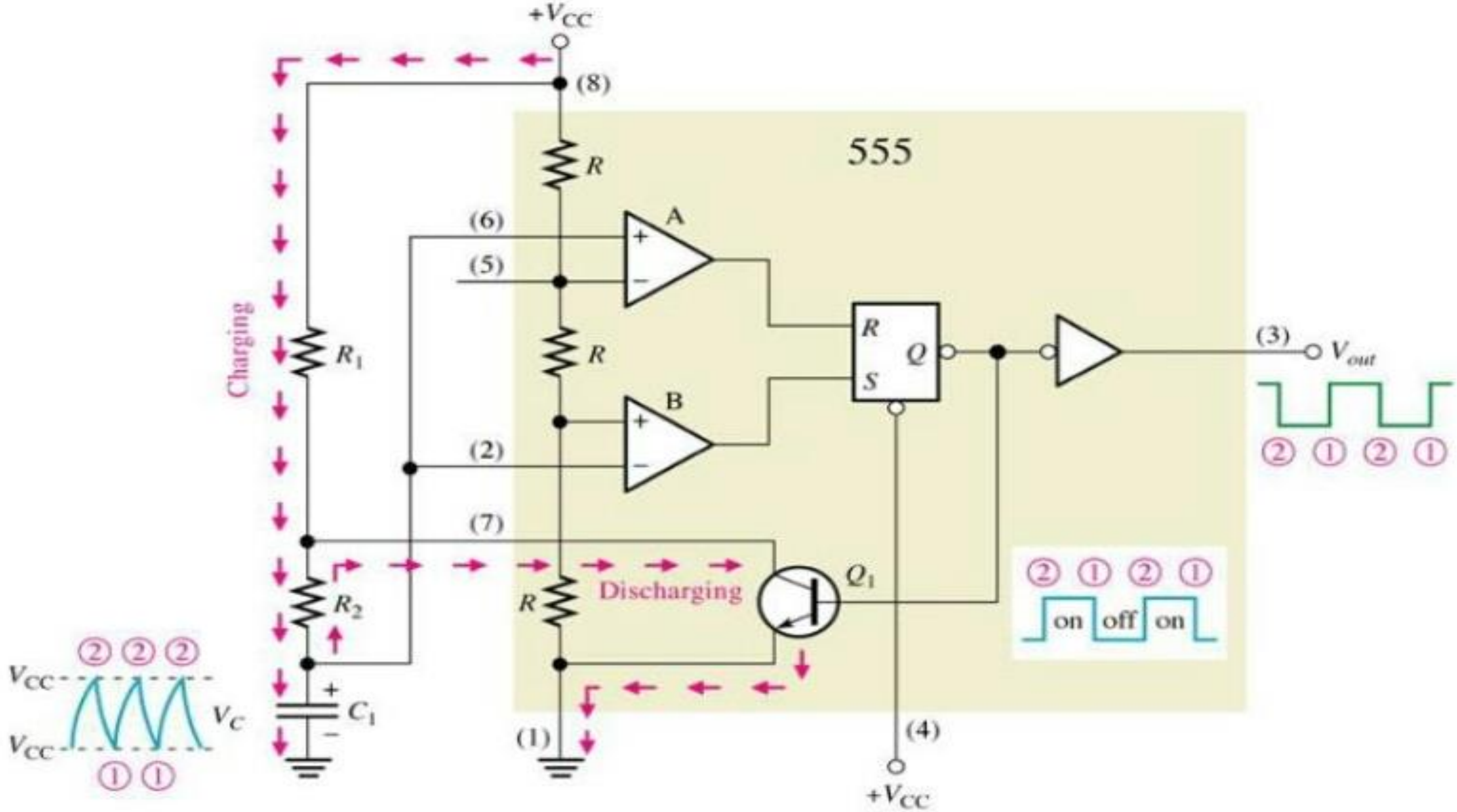


Astable operation of 555 Timer



$t_H = .7\,(R1+R2)C1 = 2.1\text{ms}$ $\quad$ $t_L = .7R2C1 = 0.7\text{ms}$

Astable operation of 555 Timer



Applications in Astable Mode

1. Square Generator
2. FSK Generator
3. Pulse Position Modulator

1.Square Generator

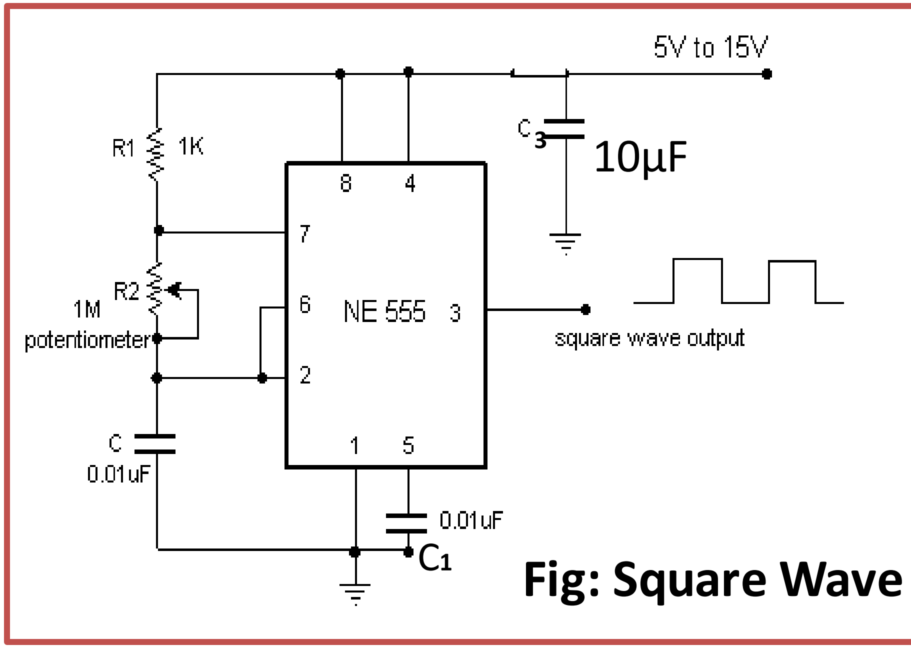


Fig: Square Wave Generator

$$DutyCycle = \frac{(R_1 + R_2)}{(R_1 + 2R_2)} X 100 = 50\%$$

$$Here\ R_1 = 0$$

- To avoid excessive discharge current through Q_1 when R_1=0 connect a diode across R_2, place a variable R in place of R_1.
- Charging path R_1 & D; Discharging path R_2 & pin 7.

2. FSK Generator

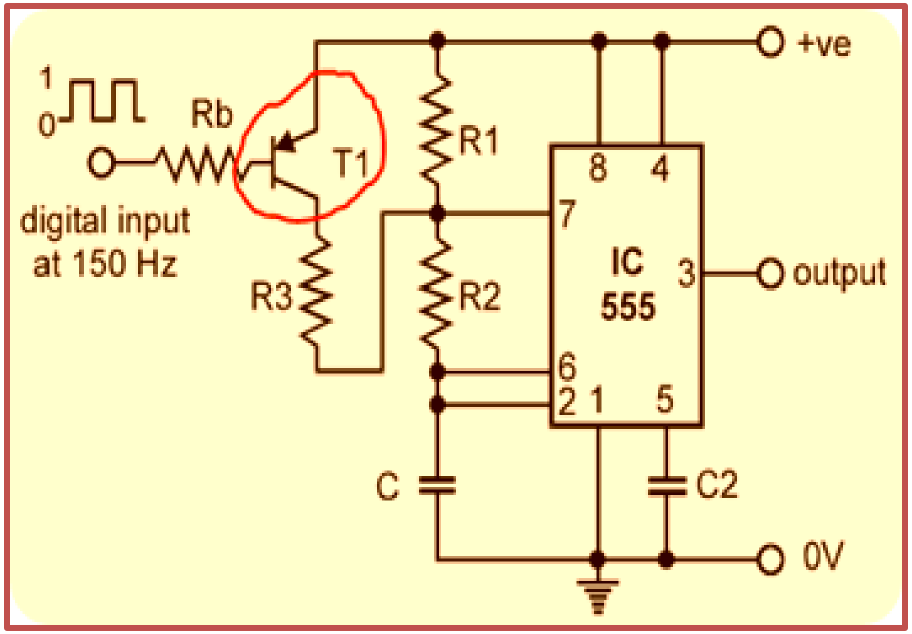


Fig: FSK Generator

Description:

- In digital data communication, binary code is transmitted by shifting a carrier frequency between two preset frequencies. This type of transmission is called Frequency Shift Keying (FSK) technique.

Contd…..

FSK Generator

- A 555 timer is astable mode can be used to generate FSK signal.
- When input digital data is HIGH, T_1 is OFF & 555 timer works as normal astable multivibrator.

The frequency of the output wave form given by,

$$f_o = \frac{1.45}{(R_1 + 2R_2)C}$$

When input digital is LOW, Q_1 is ON then R_3 parallel R_1

$$\therefore f_o = \frac{1.45}{(R_3 \| R_1 + 2R_2)C}$$

2. Pulse Position Modulator

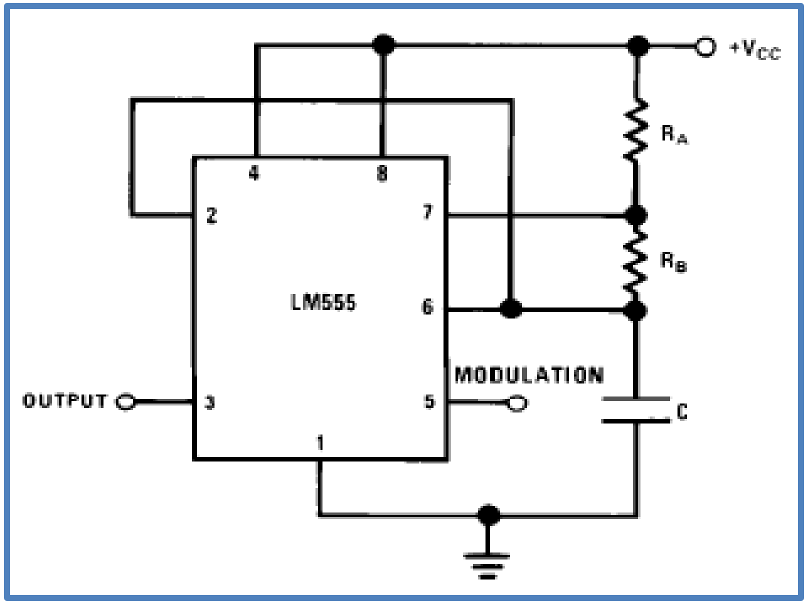


Fig (a): Pulse position Modulator

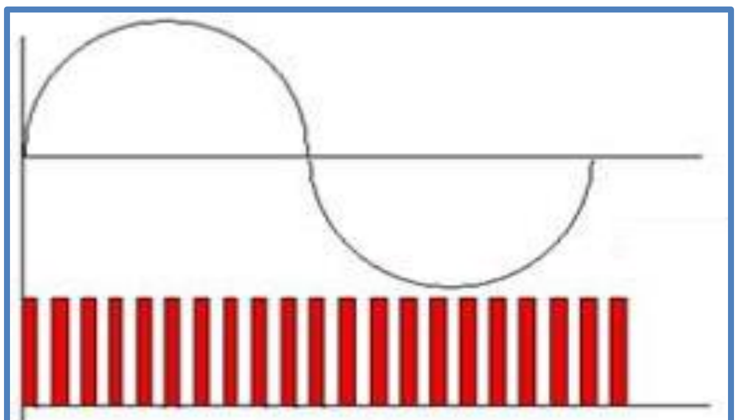


Fig (b): Output Wave Form of PPM

Description:

- The pulse position modulator can be constructed by applying a modulating signal to pin 5 of a 555 timer connected for astable operation.
- The output pulse position varies with the modulating signal, since the threshold voltage and hence the time delay is varied.
- The output waveform that the frequency is varying leading to pulse position modulation.

Astable Multivibrator

Problem:

In the astable multivibrator of fig, RA=2.2KΩ, RB=3.9K Ω and C=0.1μF. Determine the positive pulse width t_H, negative pulse width t_{Low}, and free-running frequency f_o.

Solution:

$$t_{HIGH} = 0.69(R_A + R_B)C = 0.69(2.2K\Omega + 3.9K\Omega)(0.1X\,10^{-6}) = 0.421ms$$

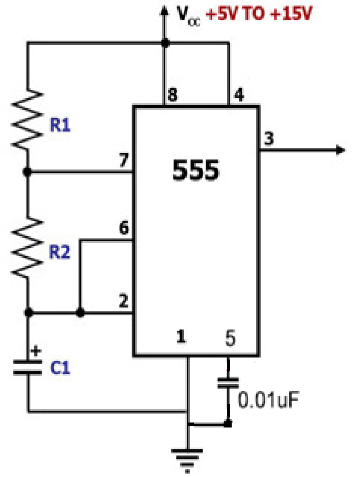
$$t_{LOW} = 0.69\,R_B\,C = 0.69(3.9K\Omega)(0.1X\,10^{-6}) = 0.269ms$$

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

Duty Cycle,

$$\%D = \frac{t_{HIGH}}{T}X100 = \frac{(R_A + R_B)}{(R_A + 2R_B)}X100 = \frac{2.2K\Omega + 3.9K\Omega}{2.2K\Omega + 2X\,3.9K\Omega}X100 = ?$$

$$\%D = \frac{t_{LOW}}{T}X100 = \frac{R_B}{(R_A + 2R_B)}X100 = \frac{3.9K\Omega}{2.2K\Omega + 2X\,3.9K\Omega}X100 = ?$$



Example: Design a 555 Oscillator to produce an approximate square-wave at 40 KHz. Let C > 470 pF.

One Possible Solution:

F=40KHz; T=25μs; $t_1=t_2=12.5\mu s$

For a square-wave $\mathbf{R_A<<R_B}$; Let $R_A=1K$ and $R_B=10K$

$t_1=0.693(R_B)(C)$; 12.5μs=0.693(10K)(C); C=1800pF

$T=0.693(R_A+2R_B)C$: T=0.693(1K+20K)1800pF

T=26.2μs; F=1/T; F=38KHz (almost square-wave).

Example: A 555 oscillator can be combined with a J-K FF to produce a 50% duty-cycle signal. Modify the above circuit to achieve a 50% duty-cycle, 40 KHz signal.

One Possible Solution:

Reduce by half the 1800pF. This will create a T=13.1μs or F=76.35 KHz (almost square-wave). Now, take the output of the 555 Timer and connect it to the CLK input of a J-K FF wired in the toggle mode (J and K inputs connected to +5V). The result at the Q output of the J-K FF is a perfect 38.17 KHz square-wave.

Comparison of Multivibrator Circuits

Monostable Multivibrator	Astable Multivibrator
1. It has only one stable state	1. There is no stable state.
2. Trigger is required for the operation to change the state.	2. Trigger is not required to change the state hence called free running.
3. Two comparators R and C are necessary with IC 555 to obtain the circuit.	3. Three components R_A, R_B and C are necessary with IC 555 to obtain the circuit.
4. The pulse width is given by T=1.1RC Seconds	4. The frequency is given by, $f_o = \frac{1}{T} = \frac{1.45}{(R_A+2R_B)C}$
5. The frequency of operation is controlled by frequency of trigger pulses applied.	5. The frequency of operation is controlled by R_A, R_B & C.
6. The applications are timer, frequency divider, pulse width modulation etc…	6. The applications are square wave generator, flasher, voltage controlled oscillator, FSK Generator etc..

Schmitt Trigger

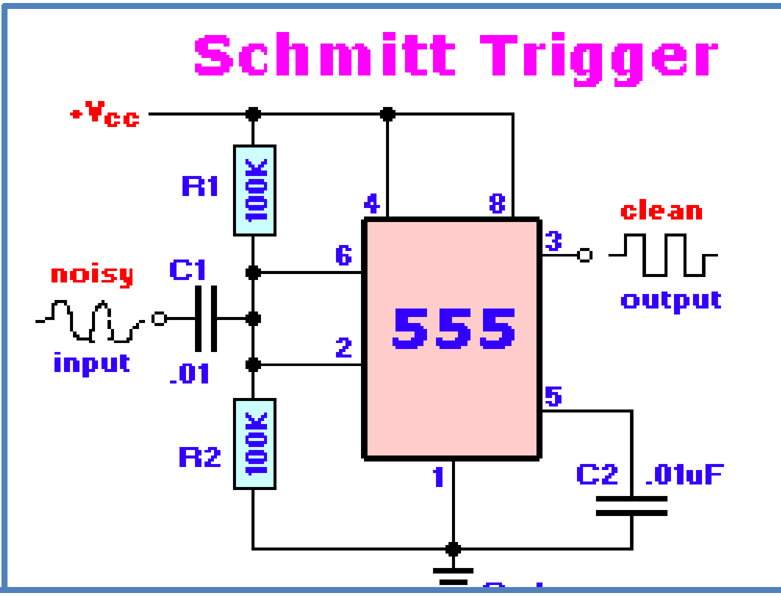


Fig (a): Circuit Diagram of Schmitt Trigger

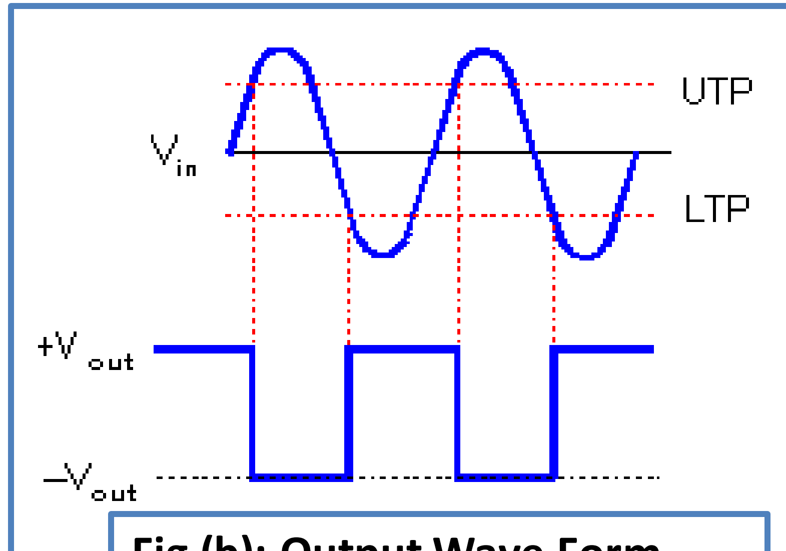


Fig (b): Output Wave Form

The use of 555 timer as a Schmitt trigger is shown in fig. Here 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 $2V_{cc}/3$ and lower comparator at $V_{cc}/3$, the bias provided by R_1 and R_2 is centered within these two thresholds.

Features of IC 555 Timer

The Features of IC 555 Timer are:

1. The 555 is a monolithic timer device which can be used to produce accurate and highly stable time delays or oscillation. It can be used to produce time delays ranging from few microseconds to several hours.

2. It has two basic operating modes: monostable and astable.

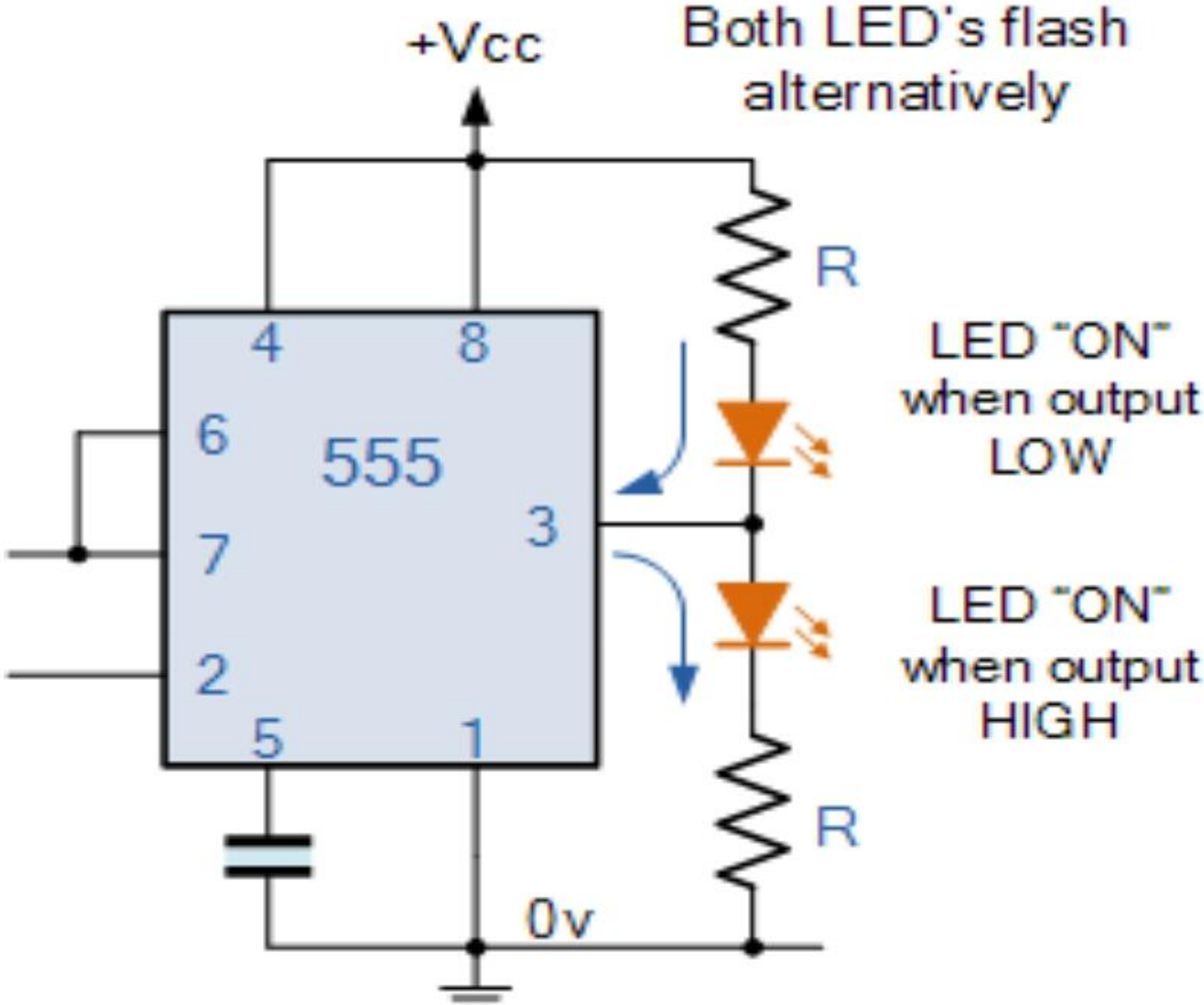
3. It is available in three packages: 8-pin metal can, 8-pin mini DIP or a 14-pin. A 14-pin package is IC 556 which consists of two 555 times.

Features of IC 555 Timer

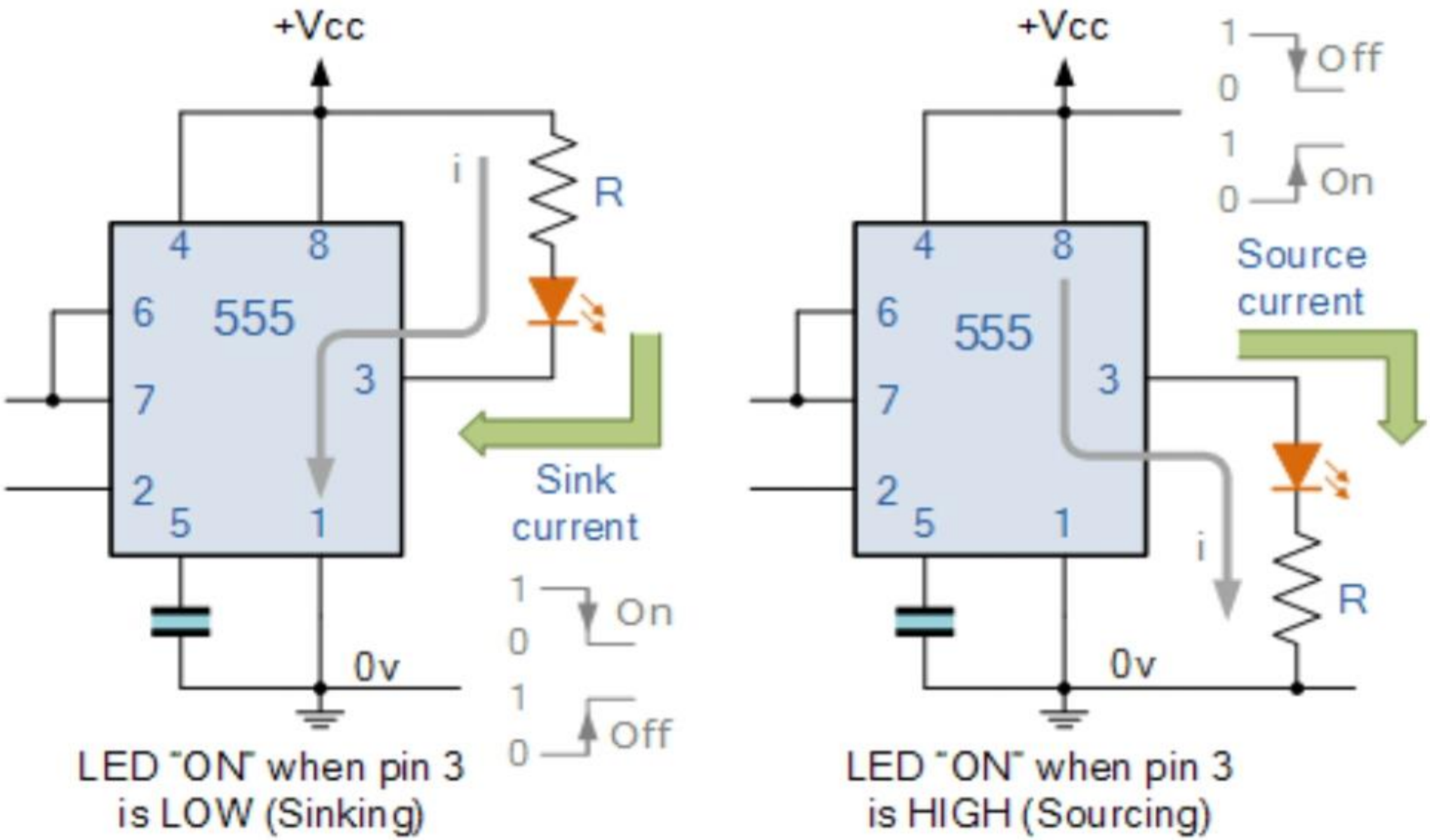
4. The NE 555(signetics) can operate with a supply voltage in the range of 4.5v to 18v and output currents of 200mA.

5. It has a very high temperature stability, as it is designed to operate in the temperature range of -55^{o}c to 125^{o}c.

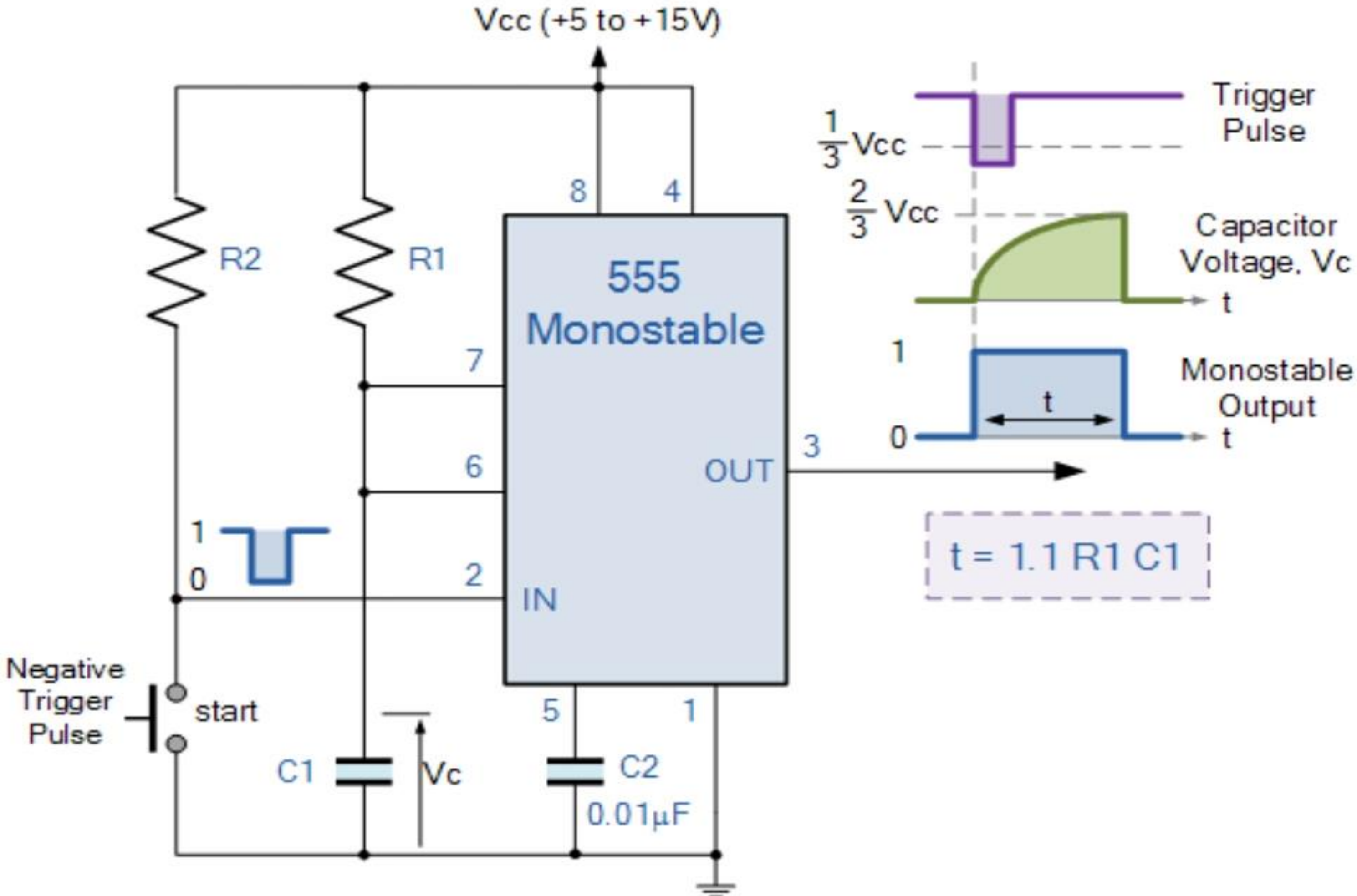
6. Its output is compatible with TTL, CMOS and Op-Amp circuits.


+Vcc
Both LED's flash alternatively
R
4
8
555
6
7
3
2
5
1
LED "ON" when output LOW
LED "ON" when output HIGH
R
0v

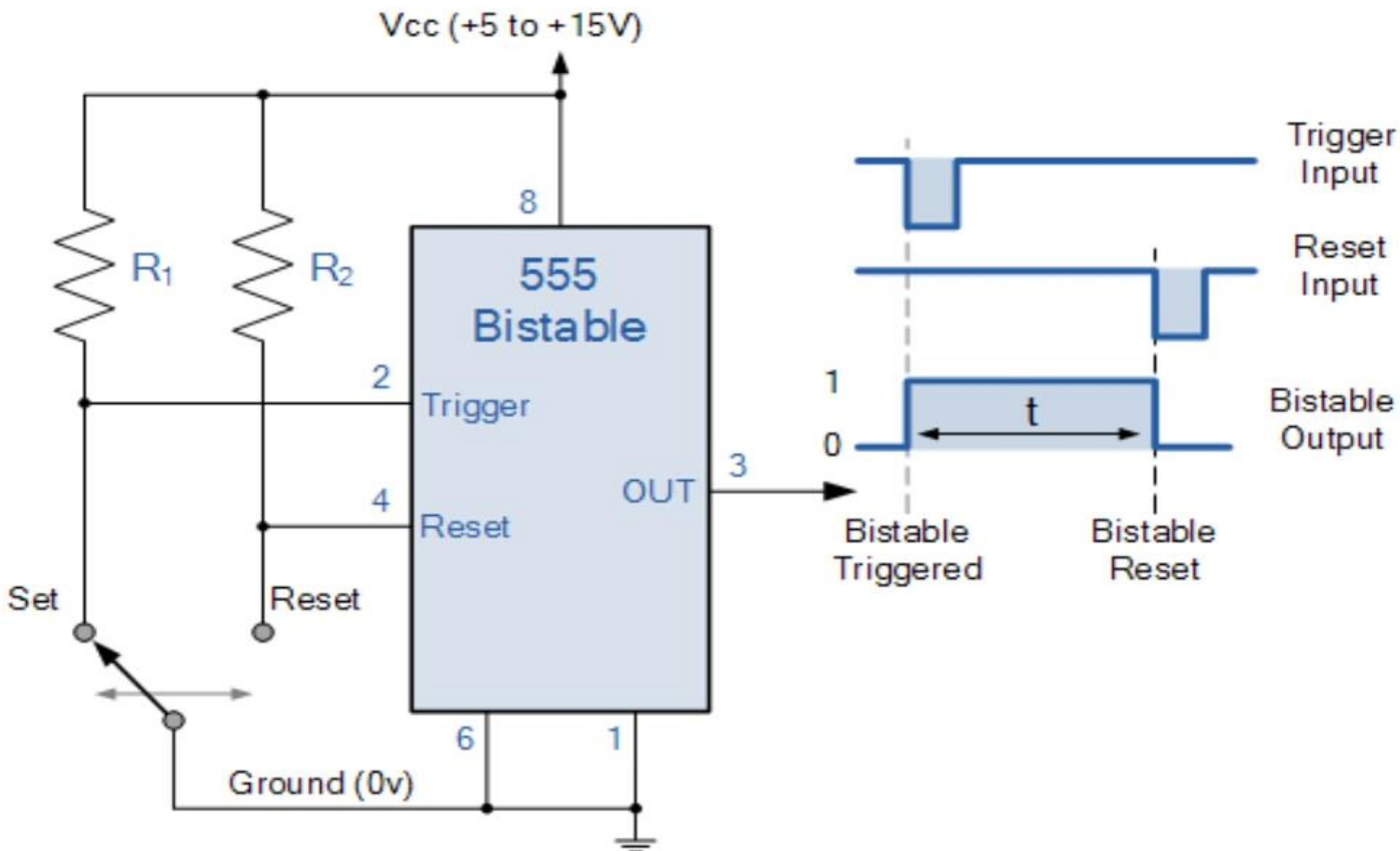
Sinking and Sourcing the 555 Timer Output

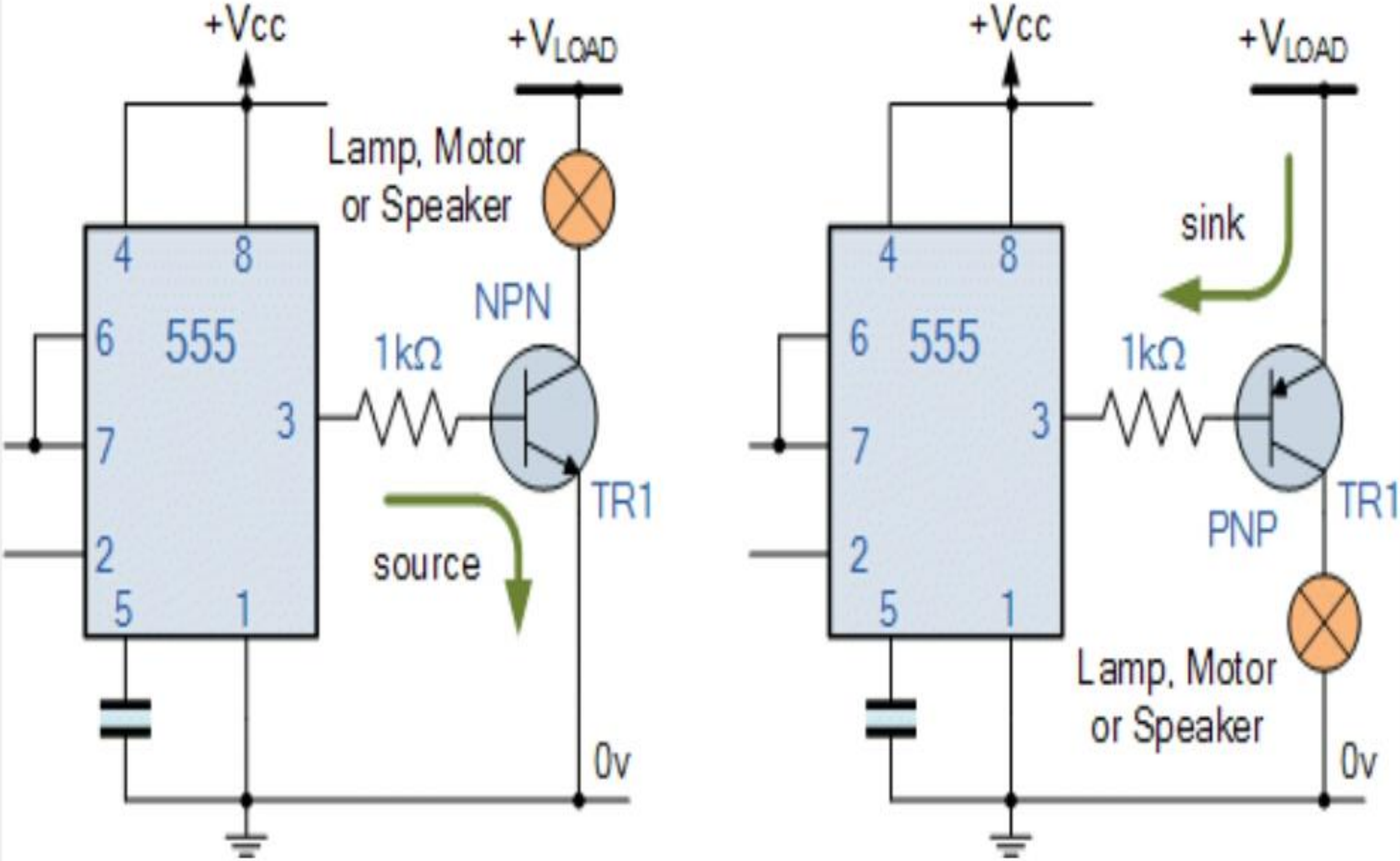


Monostable 555 Timer



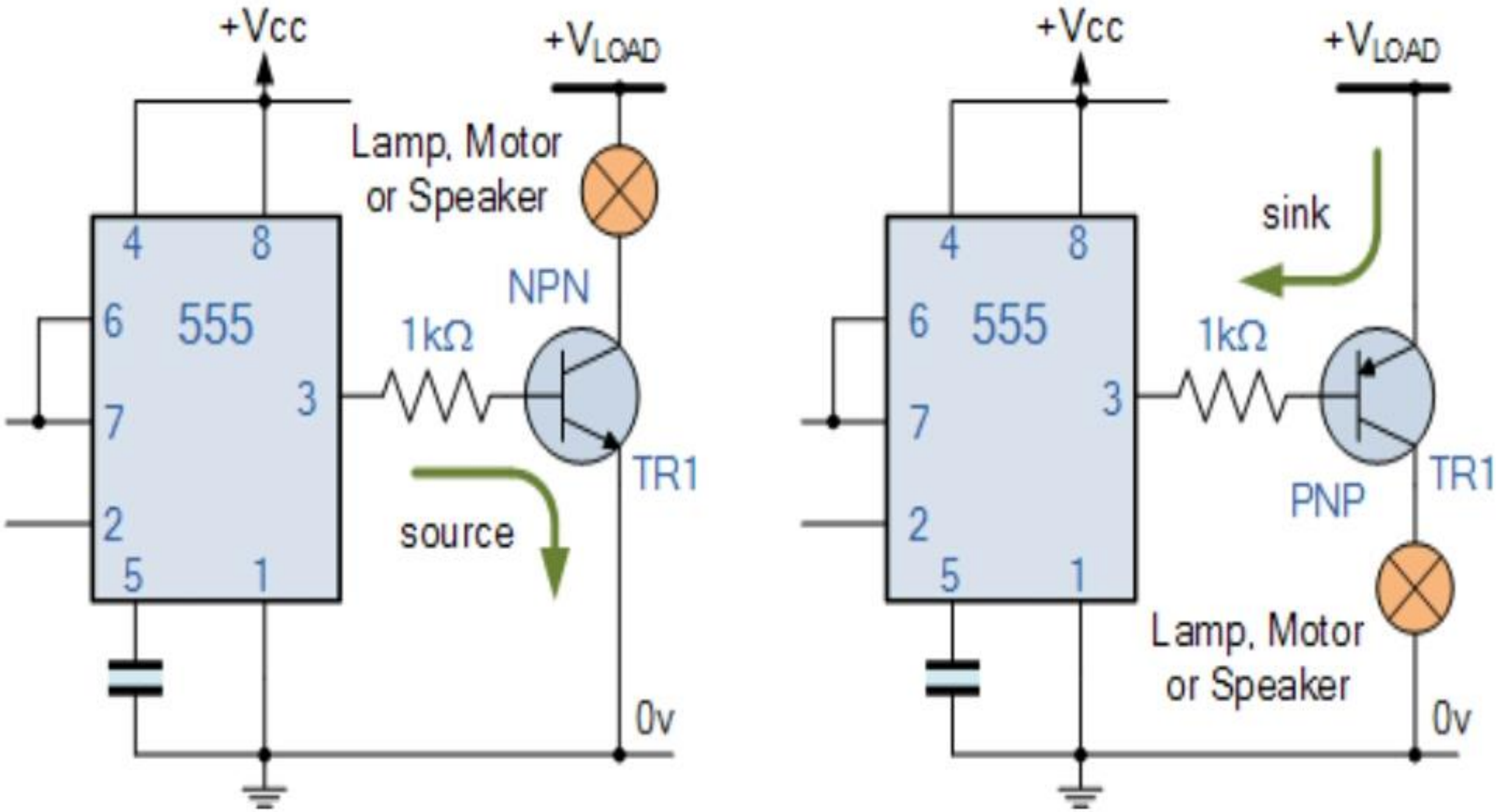
Bistable 555 Timer (flip-flop)





+Vcc
+VLOAD
Lamp, Motor
or Speaker
NPN
4
8
6
555
7
3
2
5
1
1kΩ
TR1
source
0v
+Vcc
+VLOAD
sink
4
8
6
555
7
3
2
5
1
1kΩ
TR1
PNP
Lamp, Motor
or Speaker
0v

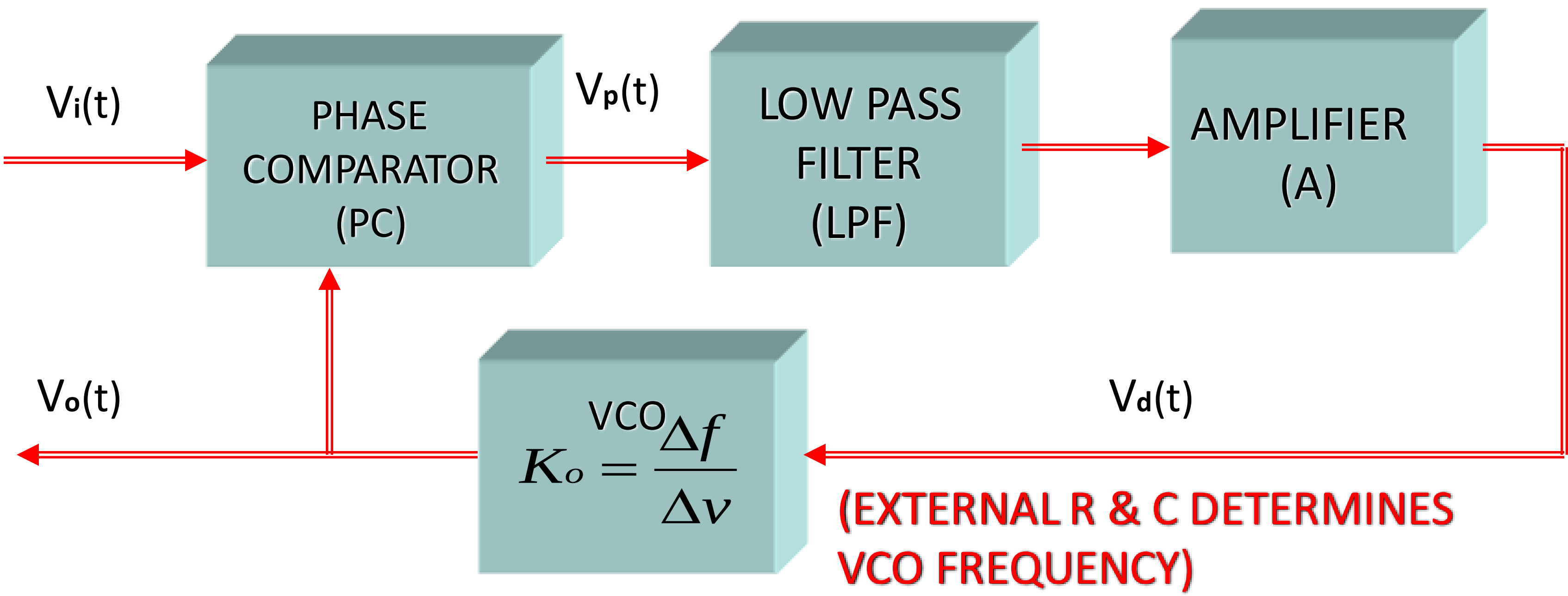
555 Timer Transistor Driver



Extra

PHASE-LOCKED LOOPS- Introduction

The phase-locked loop is a negative feedback system in which the frequency of an internal oscillator (vco) is matched to the frequency of an external waveform with some Pre-defined phase difference.



Contd.....

PHASE-LOCKED LOOPS

Phase Comparator:

- The phase comparator (phase detector) can be as simple as an exclusive-or gate (digital signals) or is a mixer (non-linear device - frequency multiplier) for analog signals.

- The phase comparator generates an output voltage $V_p(t)$ (relates to the phase difference between external signal $V_i(t)$ and vco output $V_o(t)$).

- If the two frequencies are the same (with a pre-defined phase difference) then $V_p(t) = 0$.

- If the two frequencies are not equal (with various phase differences), then $V_p(t) \neq 0$ and with frequency components about twice the input frequency.

Contd.....

PHASE-LOCKED LOOPS

Low pass filter:

- The low pass filter removes these high frequency components and $V_d(t)$ is a variable dc voltage which is a function of the phase difference.

Voltage Controlled Oscillator:

- The vco has a free-running frequency, f_o, approximately equal to the input frequency. the vco frequency varies as a function of $V_d(t)$
- The feedback loop tries to adjust the vco frequency so that:

$$V_i(t) \text{ FREQUENCY} = V_o(t) \text{ FREQUENCY}$$

THE VCO IS SYNCHRONIZED, OR LOCKED TO $V_i(t)$

Contd…..

PLL LOCK RANGE

Lock range:

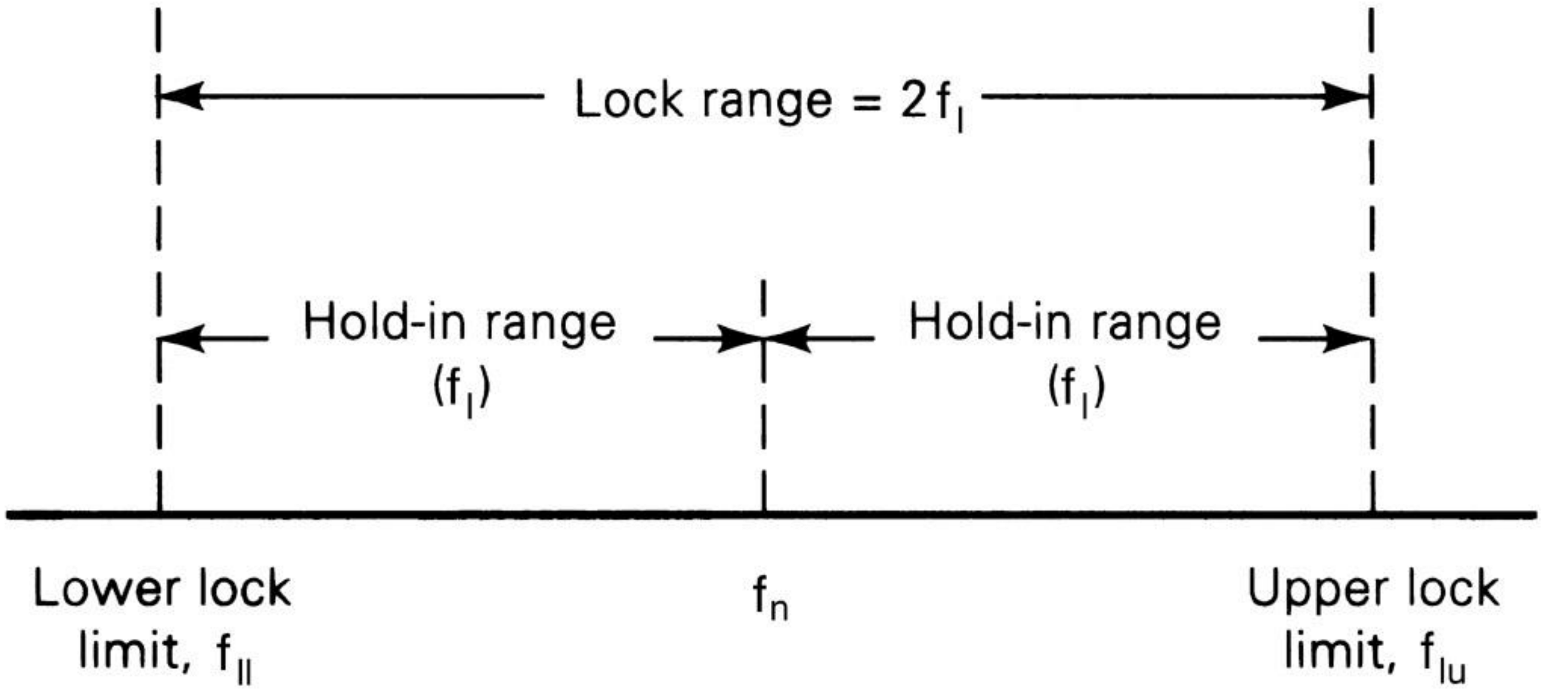
- Lock range is defined as the range of frequencies in the vicinity of the vco's Natural frequency (free-running frequency) for which the pll can maintain lock with the input signal. The lock range is also called the tracking Range.
- The lock range is a function of the transfer functions of the pc, amplifier, and vco.

Hold-in range:

- The hold-in range is equal to half the lock range
- The lowest frequency that the pll will track is called the lower lock limit. The highest frequency that the pll will track is called the upper lock limit

Contd…..

PLL LOCK RANGE



PLL CAPTURE RANGE

CAPTURE RANGE:

- Capture range is defined as the band of frequencies in the vicinity of f_o where the pll can establish or acquire lock with an input range (also called the acquisition range).

- Capture range is a function of the BW of the lpf ($\downarrow$ lpf BW $\downarrow$ capture range).

- Capture range is between 1.1 and 1.7 times the natural frequency of the vco.

The pull-in range:

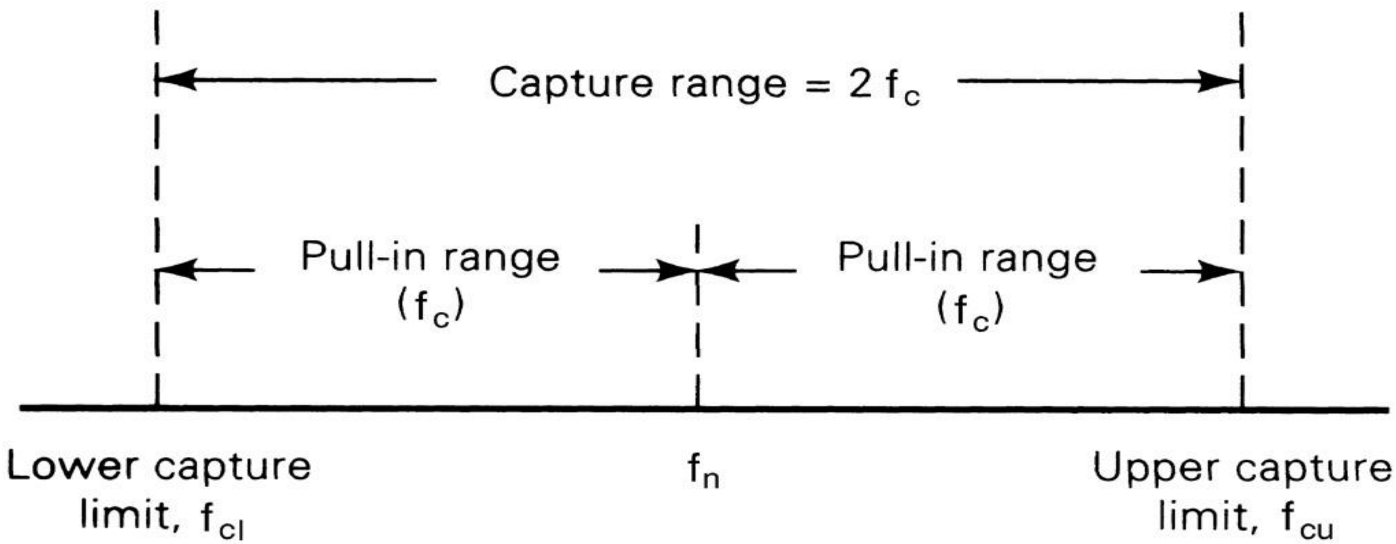
- The pull-in range is equal to half the capture range

- The lowest frequency that the pll can lock onto is called the lower capture limit

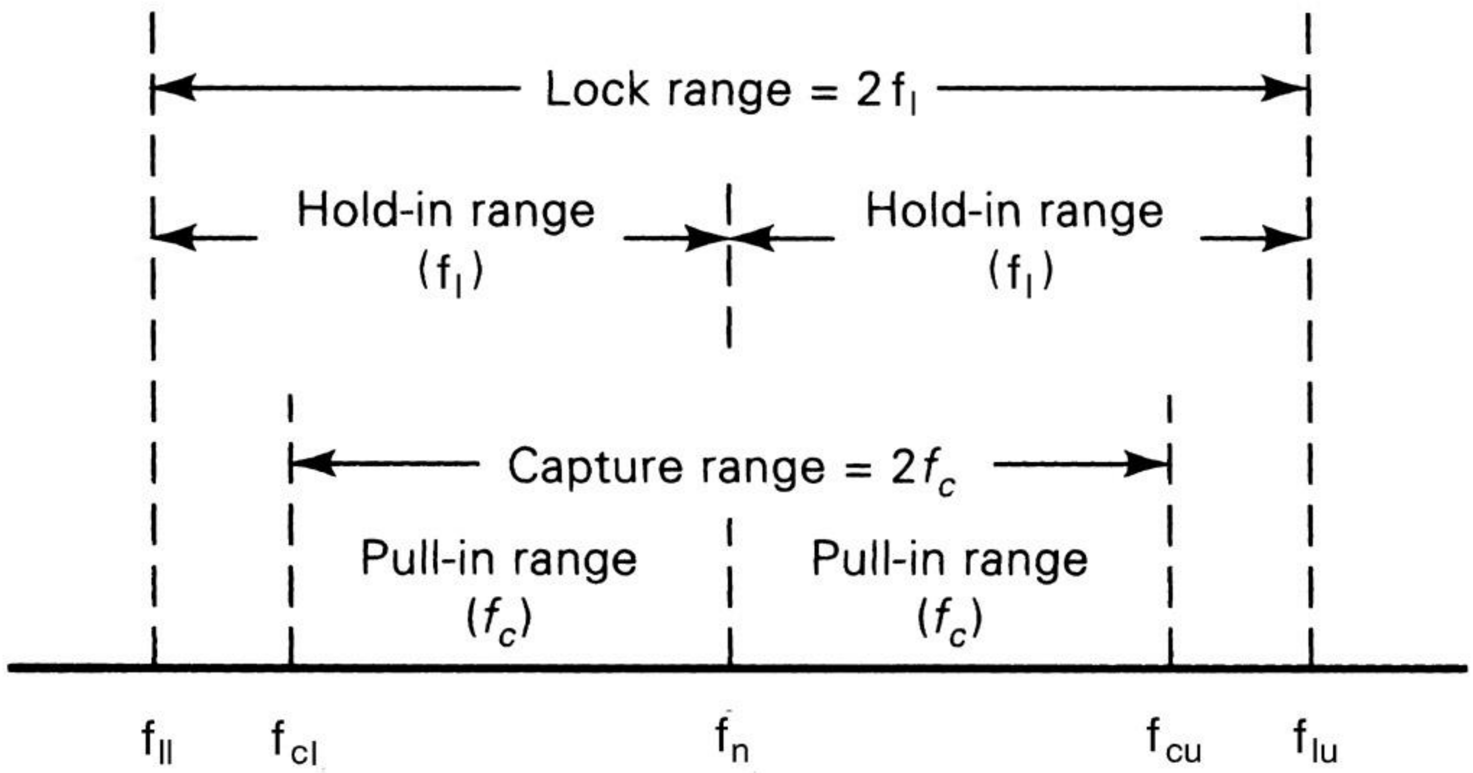
Contd….

PLL CAPTURE RANGE

- The highest frequency that the pll can lock onto is called the upper capture limit



PLL LOCK/CAPTURE RANGE

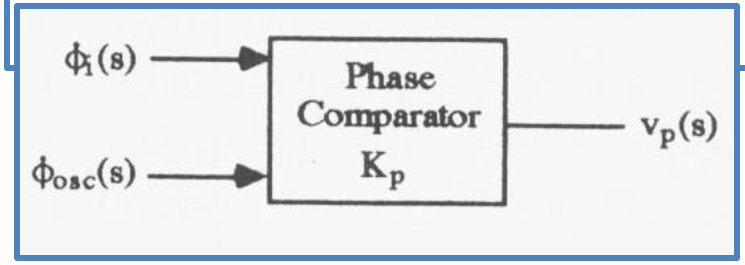


LOCK RANGE > CAPTURE RANGE

PLL-Basic Components

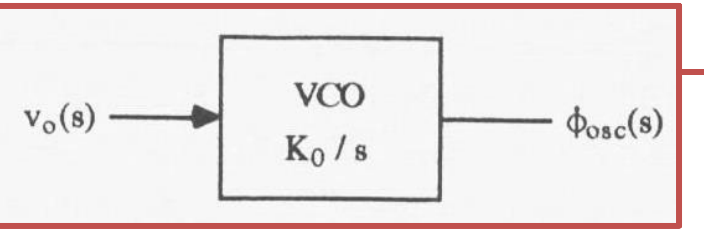
Phase detector:

- Transfer function: K_Φ [V/radians].
- Implemented as: four quad multiplier, XOR gate, state machine.



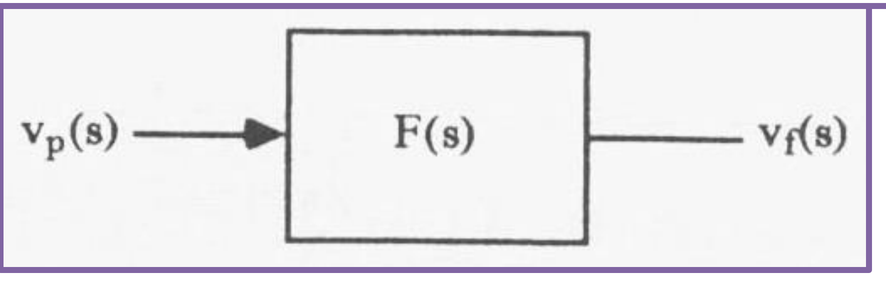
Voltage controlled oscillator (VCO):

- Frequency is the first derivative of phase.
- Transfer function: K_{VCO}/s [radians/(V•s)]

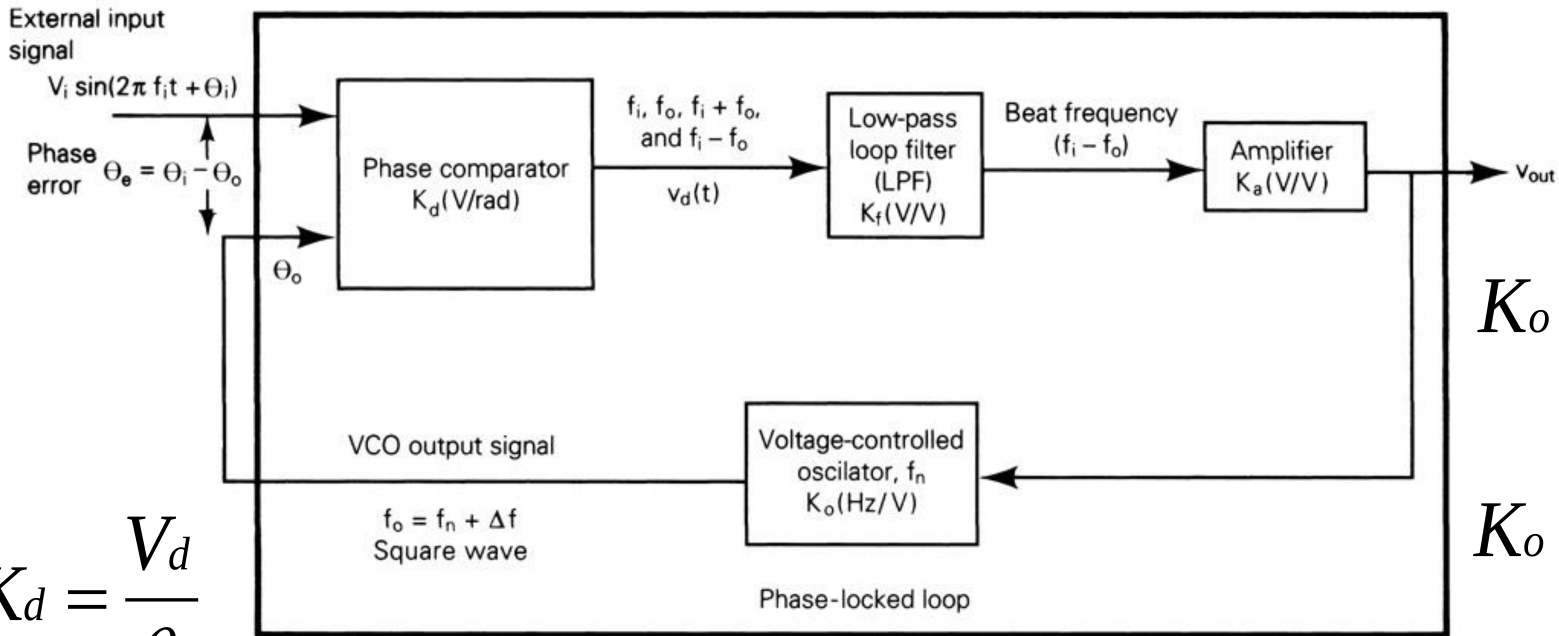


Low pass filter:

- Removes high frequency components coming from the phase detector.
- Determines loop order and loop dynamics.



PLL OPERATION-Putting All Together



(a)

$$K_o = \frac{\Delta f}{\Delta v}$$

$$K_o = \frac{\Delta f}{V_{out}}$$

$$K_d = \frac{V_d}{\theta_e}$$

$$V_d = K_d\,\theta_e$$

$$V_{out} = K_f\,K_a V_d$$

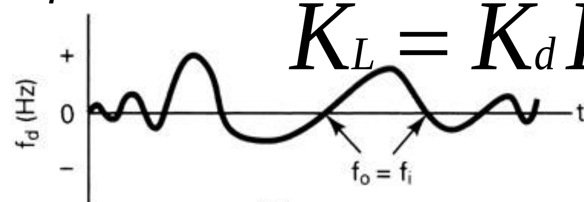
OPEN-LOOP GAIN:

$$K_L = K_d K_f K_a K_o$$

$$V_{out} = \frac{\Delta f}{K_o}$$

$$\theta_e = \frac{V_d}{K_d}$$

$$V_d = \frac{V_{out}}{K_f\,K_a}$$

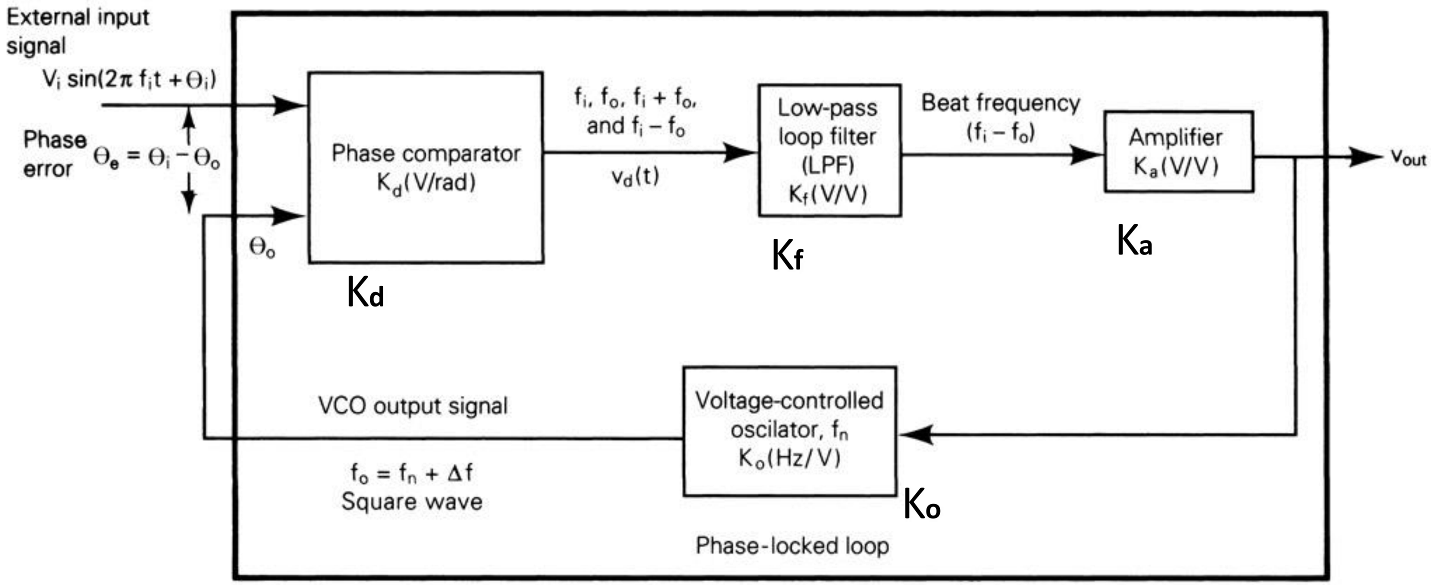


(b)

$$\Delta f = V_{out} K_o$$

$$\Delta f = f_{in} - f_n$$

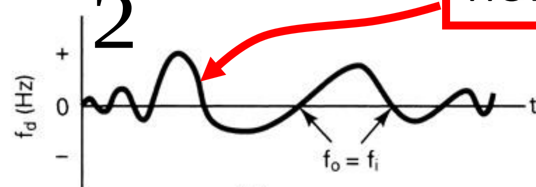
PLL OPERATION



(a)

$$V_{d\,\max} = \theta_{e\,\max} K_d = \pm \frac{\pi}{2} K_d$$

HOLD-IN RANGE

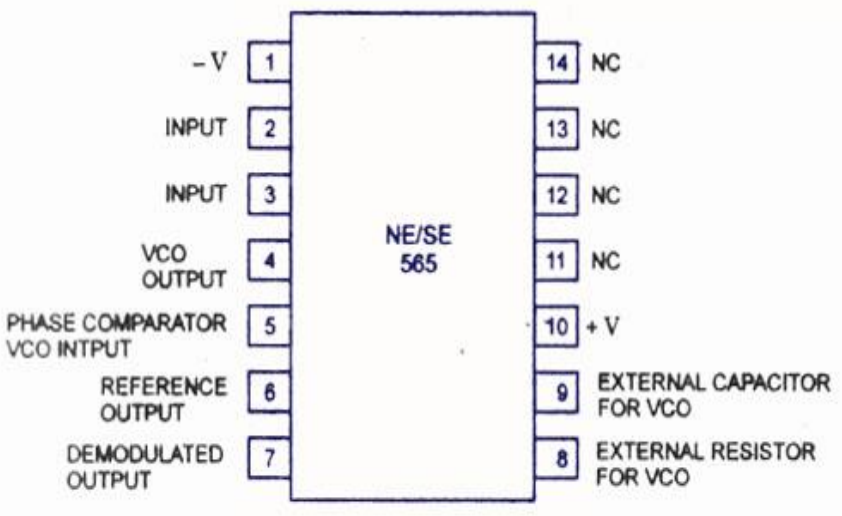


(b)

$$\pm \Delta f_{\max} = \pm \frac{\pi}{2} K_d K_f K_a K_o = \pm \frac{\pi}{2} K_L$$

$$Lock\ Range = 2\Delta f_{\max} = \pi K_L$$

PLL 565 Pin Configuration



14-Pin DIP Package

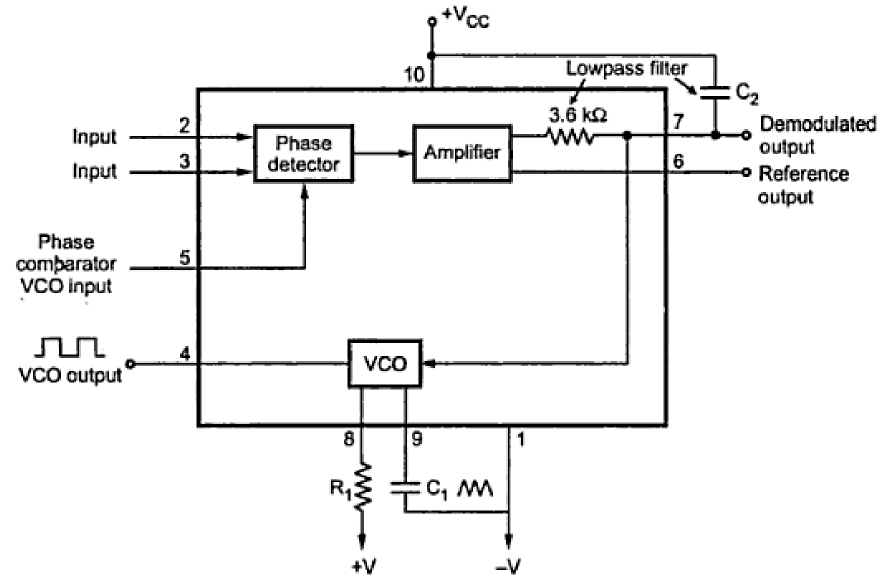


Fig. Block diagram of IC 565 PLL

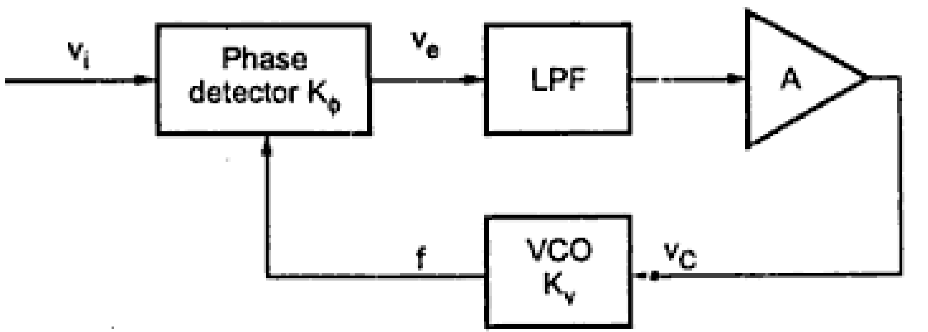


Fig. PLL block diagram to determine lock range

PLL- Example

Problem:

f_n = 200 kHz, f_i = 210 kHz, K_d = 0.2 V/rad, K_f = 1, K_a = 5, K_o = 20 kHz/V

Solution:

PLL OPEN-LOOP GAIN:

$$K_L = (.2)(1)(5)(20) = 20\ kHz/rad$$

VCO FREQUENCY CHANGE for LOCK:

$$\Delta f = f_{in} - f_n = 210 - 200 = 10\ kHz$$

PLL OUTPUT VOLTAGE:

$$V_{out} = \frac{\Delta f}{K_o} = \frac{10\ kHz}{20\ kHz/V} = .5\,V$$

Contd.....

PLL-Example

PHASE DETECTOR OUTPUT VOLTAGE:

$$V_d = \frac{V_{out}}{K_f\,K_a} = \frac{.5}{1(5)} = .1V$$

STATIC PHASE ERROR:

$$\theta e = \frac{V_d}{K_d} = \frac{.1V}{.2\,V\,/\,rad} = .5\,rad = 28.65°$$

HOLD-IN RANGE:

$$\pm\,\Delta f_{\max} = \pm\frac{\pi}{2}K_L = \pm 31.4\,kHz$$

LOCK RANGE:

$$Lock\ Range = 2\Delta f_{\max} = \pm 62.8\,kHz$$

Salient Features of 565 PLL

1. Operating frequency range =0.01Hz to 500KHz
2. Operating voltage range = ±6v to ± 12v
3. Input level required for tracking:

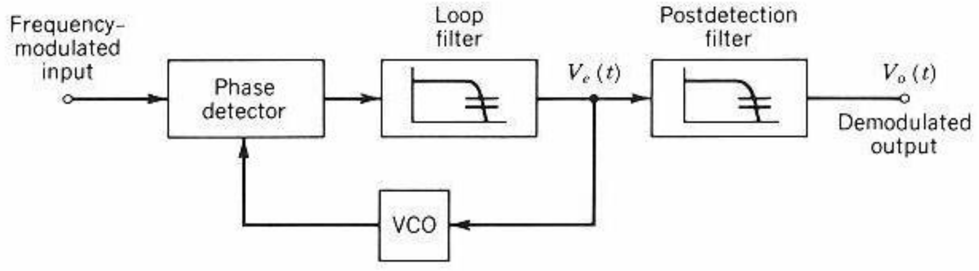
   10mv rms min to 3v peak to peak max
4. Input impedance = 10kΩ typically.
5. Output sink current : 1mA typically.
6. Output source current: 10mA typically
7. Drift in VCO Centre frequency: 300 PPM/ ^{o}c
8. Drift in VCO Centre frequency with supply voltage: 1.5 percent/V_{max}
9. Triangle wave amplitude: 2.4 V_{pp} at ± 6v supply voltage.
10. Square wave amplitude: 5.4 V_{pp} at ± 6v supply voltage.
11. Bandwidth adjustment range: < ± 1 to ± 60%

PLL APPLICATIONS

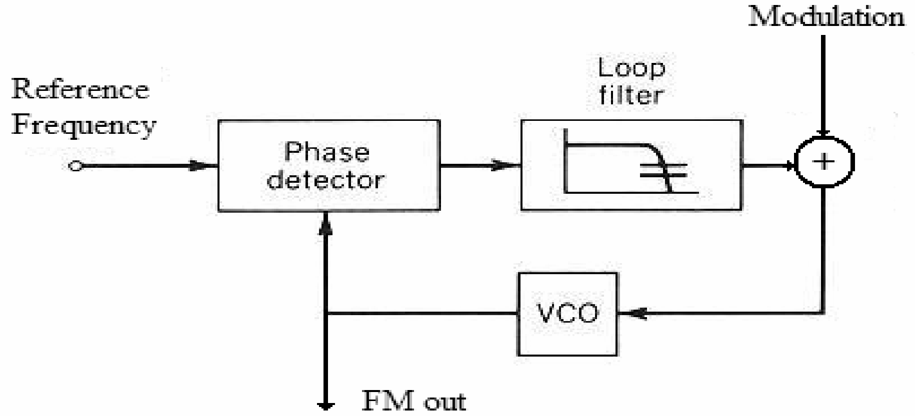
- Analog and digital modulation
- Frequency shift keying (fsk) decoders
- Am modulation / demodulation
- Fm modulation / demodulation
- Frequency synthesis
- Frequency generation

PLL APPLICATIONS

1.FM Demodulator:



2.FM Modulator:



Voltage Controlled Oscillator (VCO)

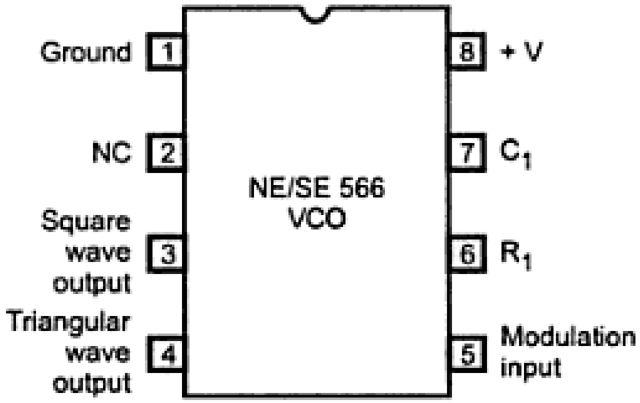


Fig. Pin diagram of IC 566 VCO

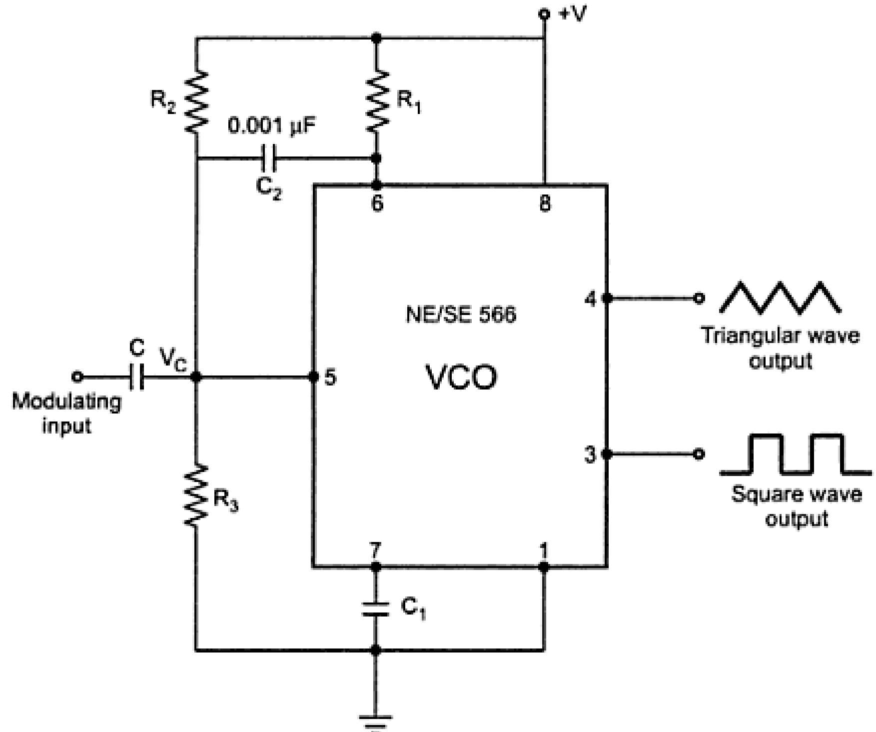


Fig. Typical connection diagram of 566 VCO

A voltage controlled oscillator is an oscillator circuit in which the frequency of oscillations can be controlled by an externally applied voltage

VCO Operation

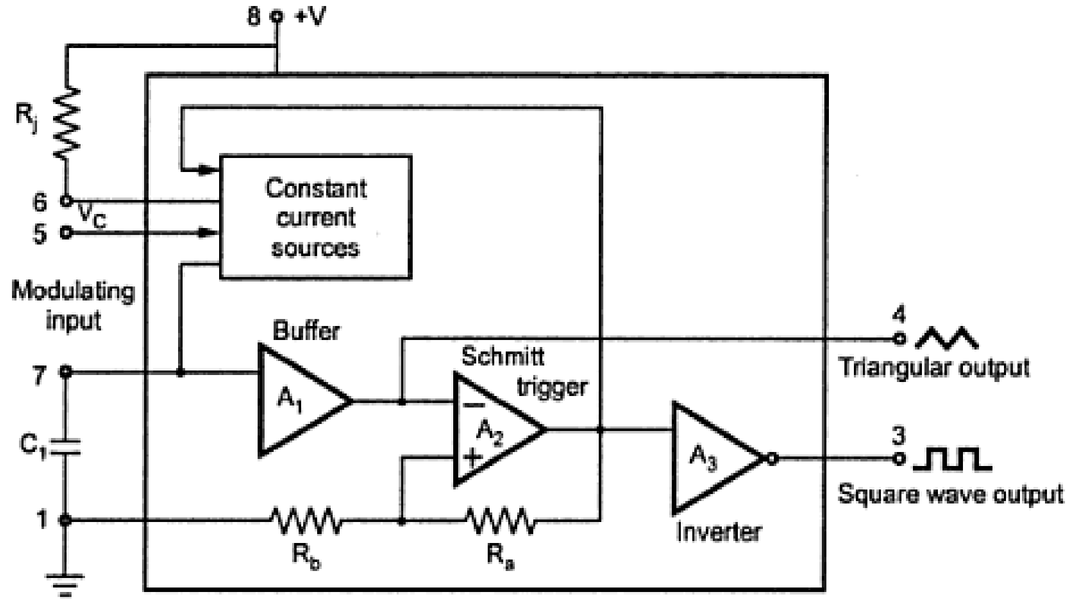


Fig. Block diagram of NE/SE 566 VCO

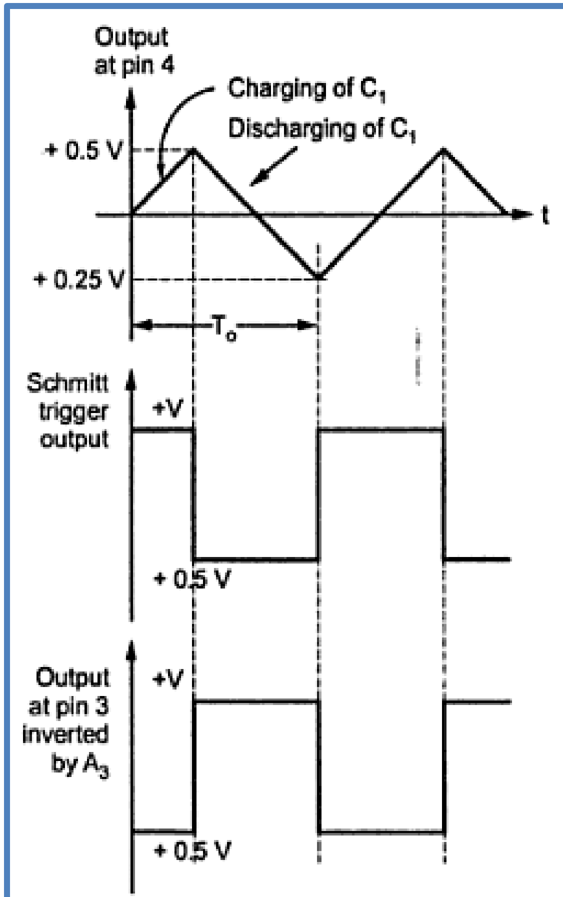


Fig. Waveforms for VCO

VCO Analysis

Derivation of Voltage to Frequency Conversion Factor

The voltage to frequency conversion factor is an important factor of IC of 566. It is denoted as K_v, and defined as,

$$K_v = \frac{\Delta f_o}{\Delta V_C} \quad \ldots(1)$$

Here ΔV_C is the change in control voltage producing corresponding change of Δf_o in the frequency.

Let $\quad f'_o$ = New frequency

f_o = Original frequency $\quad \ldots(2)$

$\therefore \quad \Delta f_o = f'_o - f_o$

While V_C is changed by ΔV_C to achieve this,

From the expression of f_o,

$$f'_o = \frac{2\,[+V-(V_C-\Delta V_C)]}{C_1 R_1(+V)} \quad \ldots(3)$$

and

$$f_o = \frac{2\,[+V-V_C]}{C_1 R_1(+V)} \quad \ldots(4)$$

$$\therefore \quad \Delta f_o = f_2 - f_1 = \frac{2\Delta V_C}{R_1 C_1(+V)} \quad \ldots(5)$$

$$\therefore \quad \Delta V_C = \frac{R_1 C_1 \Delta f_o(+V)}{2} \quad \ldots(6)$$

Contd.....

VCO Analysis

With no modulating input voltage,

Control voltage $V_C = (7/8)\ (+V)$

if f_o is original frequency then,

$$f_o = \frac{2\left[+V - \frac{7}{8}(+V)\right]}{R_1C_1(+V)} = \frac{0.25}{R_1C_1} \qquad \ldots(7)$$

Using value of $R_1\ C_1$ from equation (6) in equation (7),

$$f_o = \frac{0.25}{\dfrac{2\Delta V_C}{\Delta f_o(+V)}}$$

$$\therefore \qquad K_v = \frac{\Delta f_o}{\Delta V_C} = \frac{f_o}{0.125(+V)}$$

$$\therefore \qquad \boxed{K_v = \frac{8\,f_o}{(+V)}} \quad \text{where } f_o = \text{original frequency}$$

This is the required voltage to frequency conversion factor.

Features of VCO

Features of 566 VCO

1. Wide supply voltage range 10 V to 24 V.
2. Very linear modulation characteristics.
3. High temperature stability.
4. Excellent power supply rejection.
5. 10 to 1 frequency range with fixed C_1.
6. The frequency can be controlled by means of current, voltage, resistor, or capacitor.

Applications of VCO

The various applications of VCO are:

1. Frequency Modulation.
2. Signal Generation (Triangular or Square Wave)
3. Function Generation.
4. Frequency Shift Keying i.e. FSK demodulator.
5. In frequency multipliers.
6. Tone Generation.

VCO

Example : *For a 566 VCO shown in the Fig. 5.7 +V = 10 V,* $R_2 = 1.2\ k\Omega$ *and* $R_1 = R_3 = 10\ k\Omega$ *with* $C_1 = 0.001\ \mu F$.

a) Calculate the frequency of output.

b) Calculate the variation in f_o *if* V_C *is varied between 7.7 V and 9.5 V.*

c) Draw the square wave output if the modulating input is sine wave.

Solution : (a) R_2 and R_3 form potential divider.

$$\therefore \quad V_C = R_3 \times \frac{+V}{R_2 + R_3} = \frac{10 \times 10}{1.2 + 10}$$

$$= 8.928\ V$$

$$\therefore \quad f_o = \frac{2(+V - V_C)}{C_1 R_1 (+V)} = \frac{2(10 - 8.928)}{0.001 \times 10^{-6} \times 10 \times 10^3 \times 10}$$

$$= 21.44\ kHz$$

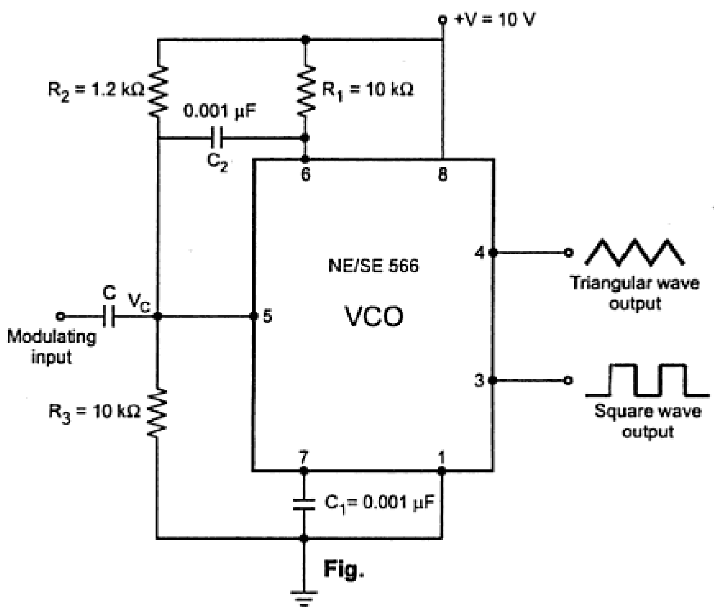


Fig.

Contd....

VCO

(b) For $V_C = 7.7$ V,

$$f_{o1} = \frac{2(10-7.7)}{0.001\times10^{-6}\times10\times10^{3}\times10}$$

$$= 46 \text{ kHz}$$

For $V_C = 9.5$ V,

$$f_{o2} = \frac{2(10-9.5)}{0.001\times10^{-6}\times10\times10^{3}\times10}$$

$$= 10 \text{ kHz}$$

The change in output frequency is 46 – 10 = 36 kHz.

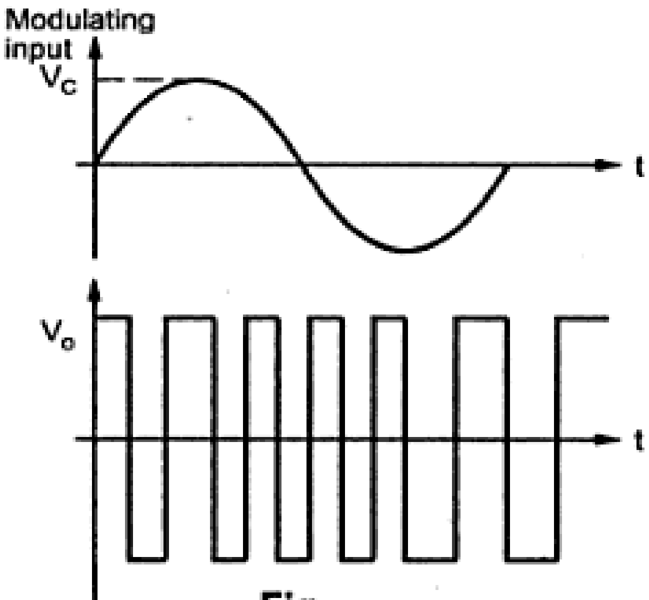
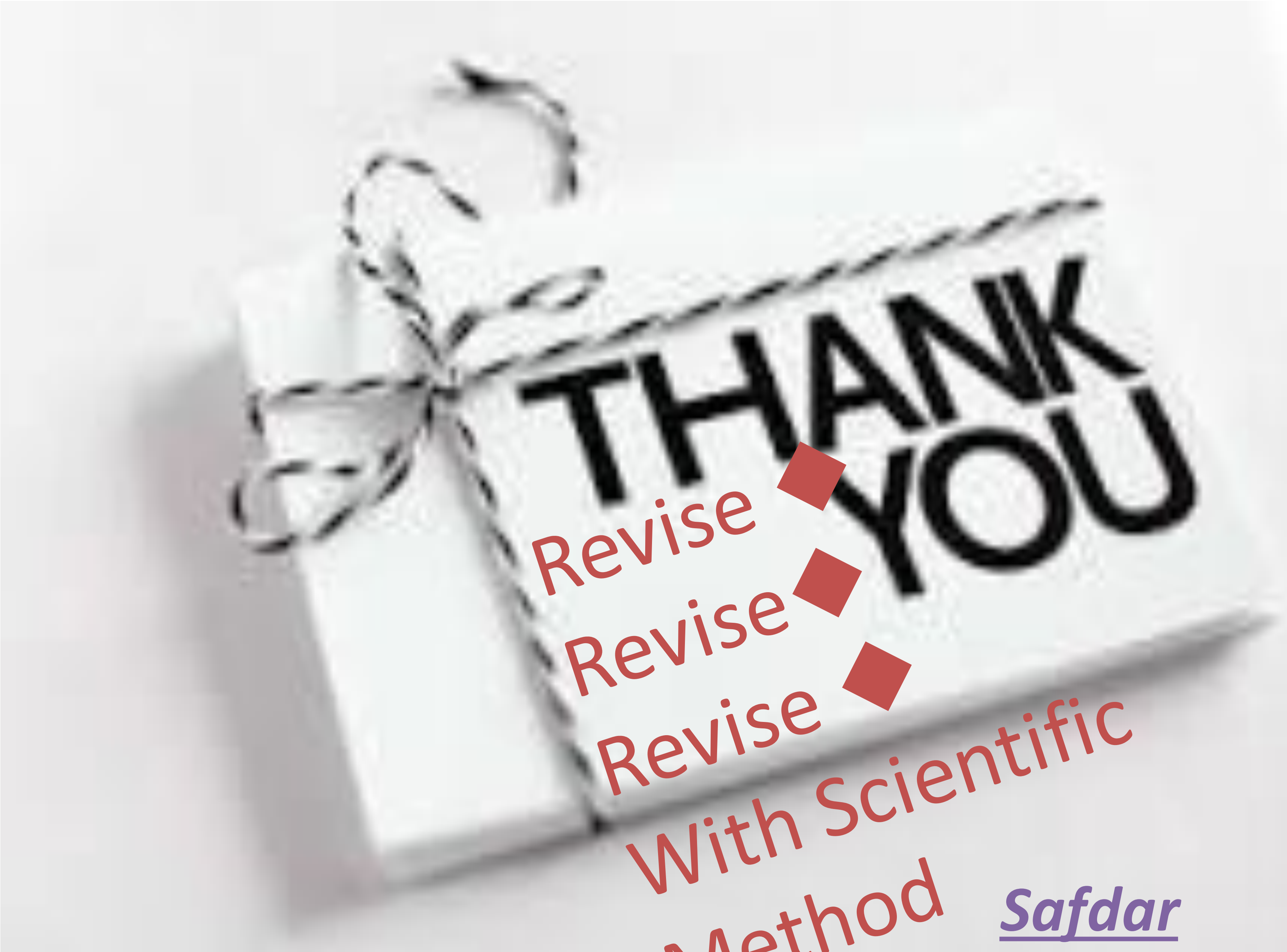


Fig.

(c) It can be seen that as V_C increases frequency decreases. When modulating input is a sine wave then during positive half cycle V_C increases and frequency decreases. While in negative half cycle, the frequency increases. So the square wave output waveform is as shown in the Fig.

This example explains the use of 566 to generate FM.


Make
NOTES



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