Oscillator, Multivibrator

Oscillators

Oscillators are circuits that produce a continuous signal of some type without the need of an input.

These signals serve a variety of purposes such as communications systems, digital systems (including computers), and test equipment

Oscillator Multivibrator

↓

Generate repatative signal of continuous form

- ↳ Sine
- ↳ square
- ↳ triangle

Oscillators: continued..

❖ An oscillator is a circuit that produces a repetitive signal from a dc voltage supply.

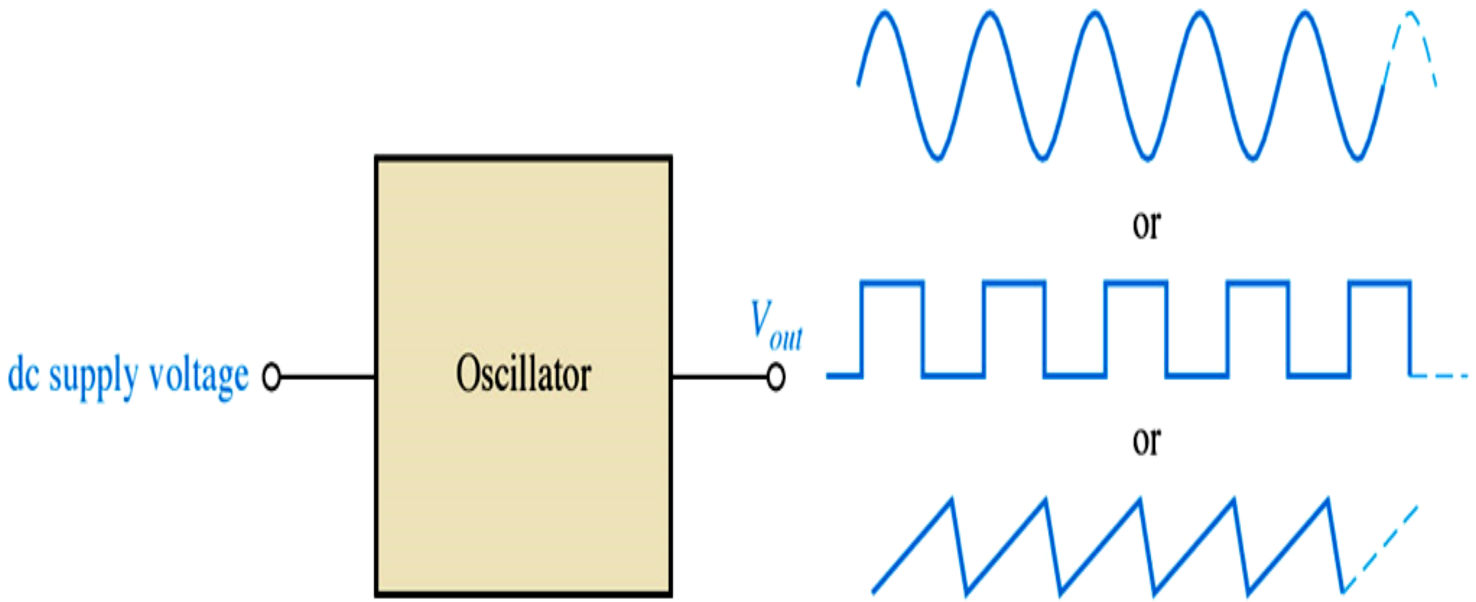
❖ The **feedback oscillator** relies on a **positive feedback** of the output to maintain the oscillations.

❖ The **relaxation oscillator** makes use of an RC timing circuit to generate a non-sinusoidal signal such as square wave.

Resistor
Capacitor

discharging is used for timing

Oscillators: continued..



Types of Oscillator

1. RC Oscillator - Wien Bridge Oscillator
   - Phase-Shift Oscillator
2. LC Oscillator - Crystal Oscillator
3. Relaxation Oscillator

multivibrator Circuit

Relaxation Oscillator

Relaxation oscillators make use of an RC timing and a device that changes states to generate a periodic waveform (non-sinusoidal) such as:

1. Triangular-wave
2. Square-wave
3. Sawtooth

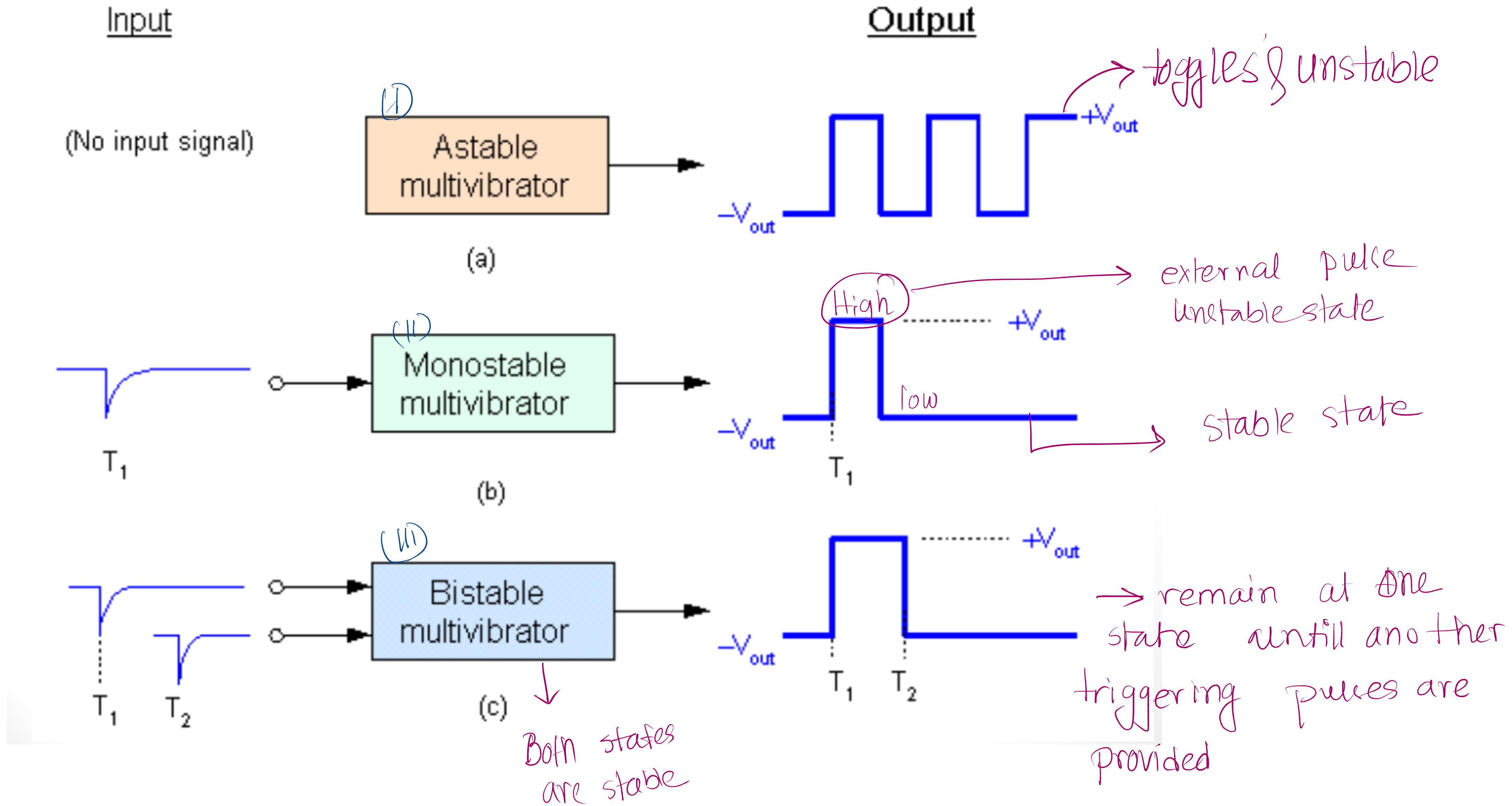
What are Multivibrator circuits?

Multivibrator circuits refer to the special type of electronic circuits used for generating pulse signals. These pulse signals can be rectangular or square wave signals. They generally produce output in two states: **high** or **low**. A specific characteristic of multi-vibrators is the use of passive elements like resistor and capacitor to determine the output state.

Multivibrator circuits are used to implement relaxation oscillators, timers, flip-flops etc.

Types of Multivibrators

→ Squareware / Pulse ware

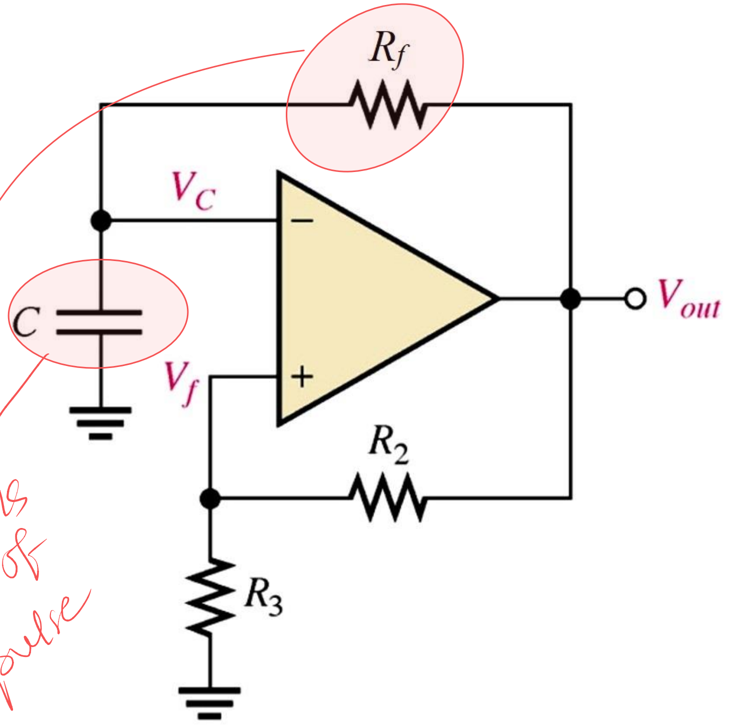


no input control to control it

Astable Multivibrator

- ✓An astable circuit is one that has two states and it is not stable in either cases.
- ✓It continually switches from one state to the other. Suitably tailored in a circuit it can function as an oscillator, regularly switching from one state to another.
- ✓Within the circuit it is normal to use an RC element to control the frequency of the Astable multivibrator.
- ✓LC elements can also be used but they are less convenient and more costly in view of the coil, especially as astable oscillators tend to be used for relatively low frequencies and the coils tend to be large for these frequencies

Astable Multivibrator using OpAmp



Controls value of the pulse

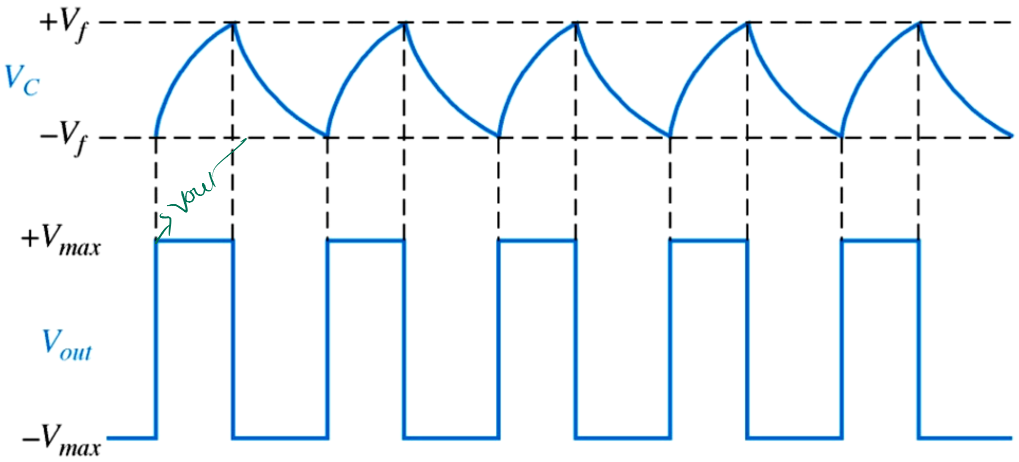
$$\lambda = \frac{R3}{R2 + R3}$$

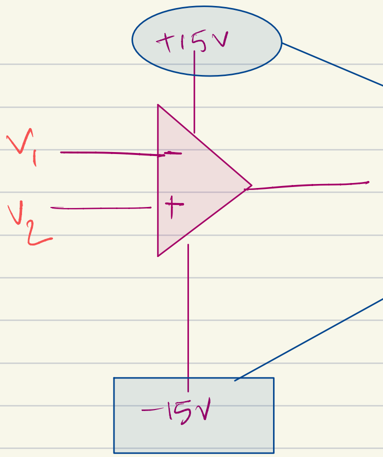
$$T = 2R_f\, C \times \ln\left[\frac{1+\lambda}{1-\lambda}\right]$$

❖ Working principle is similar to Schmitt trigger or Comparator circuit.

❖ The charging and discharging of the capacitor cause the op-amp to switch states rapidly and produce a square wave.

❖ The RC time constant determines the frequency.





Supplies (output within this range if no other things are provided)

$V_2 > V_1$

$V_{out} = +V_{sat}\ (+15V)$ High

$V_2 < V_1$

$V_{out} = -V_{sat}\ (-15V)$ Low

toggles between this two signals to generate pulse signal

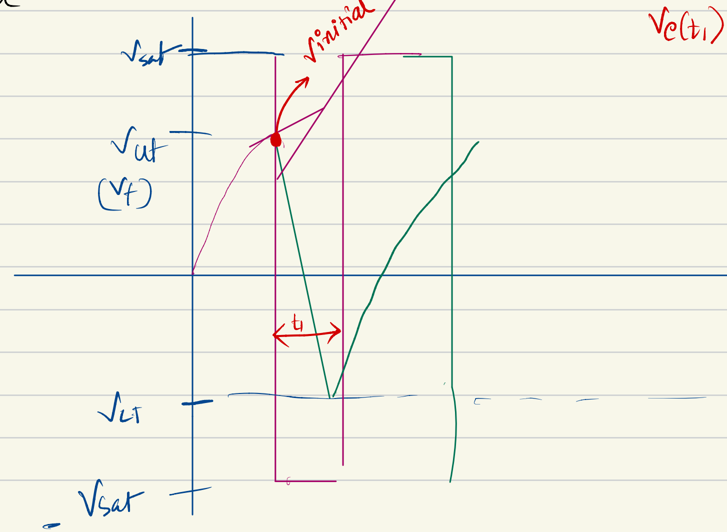
$$V_f = \frac{R_3}{R_2 + R_3} V_{out}$$

$$\boxed{= \frac{R_3}{R_2 + R_3} V_{sat}}$$ → upper threshold

$$V_f = V_{LT} = \underbrace{\frac{R_3}{R_2 + R_3}}_{\lambda} (-V_{sat})$$

$$V_c(t) = V_{final} + [V_{initial} - V_{final}]\, e^{-t/RC}$$

$$V_c(t_1) = (-V_{sat}) + [\lambda V_{sat} - (\underbrace{-V_{sat}}_{\text{reach করতে চায়}})]\, e^{-t/RC}$$



$$V_c(t) = V_{Final} + [V_{Initial} - V_{Final}]\, e^{-t/RC}$$

$$\Rightarrow V_c(t_1) = (-V_{sat}) + [\lambda V_{sat} - (-V_{sat})]\, e^{-t_1/RC}$$

$$\Rightarrow -\lambda V_{sat} = -V_{sat} + [\lambda V_{sat} + V_{sat}]\, e^{-t_1/RC}$$

$$\rightarrow t \Rightarrow (V_{sat} - \lambda V_{sat}) = (V_{sat} + \lambda V_{sat})\, e^{-t_1/RC}$$

$$\Rightarrow \frac{1-\lambda}{1+\lambda} = e^{-t_1/RC}$$

$$\Rightarrow t_1 = RC \ln\left(\frac{1+\lambda}{1-\lambda}\right)$$

Initially capacitor voltage is 0. it will start charging. As it starts crossing UT the output side will fall since negative ~~post~~ voltage is greater then there will be a switch inverting

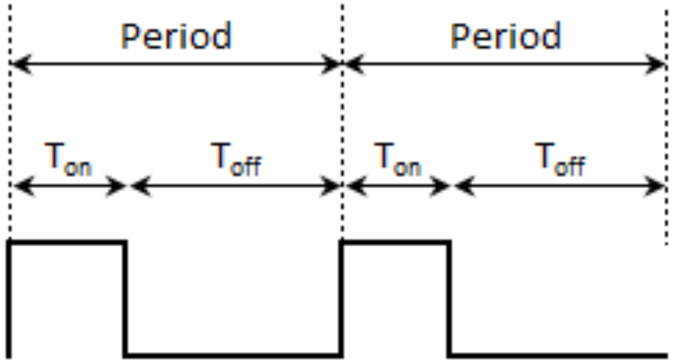
Duty Cycle

In general terms duty cycle means proportion of time for which device is operated. In terms of square wave signal it defines the percentage of time for which signal is at logic high level. For square wave it can be calculated as (high time / (high time + low time))

Duty cycle is the ratio of time a load or circuit is **ON** compared to the time the load or circuit is **OFF**.

Duty cycle, sometimes called "duty factor," is expressed as a percentage of **ON** time. A 60% duty cycle is a signal that is **ON** 60% of the time and **OFF** the other 40%

Duty cycle of 50% means that the low time and high time of the signal is same.

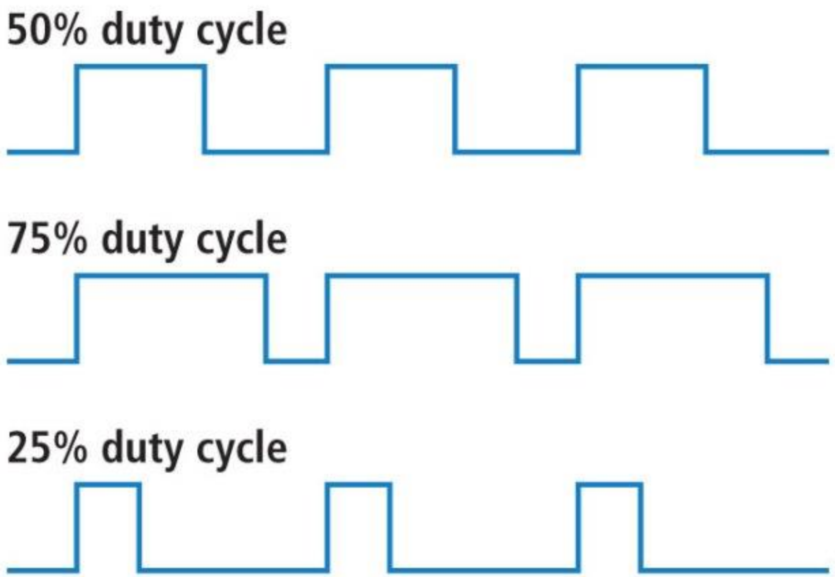


Period = 1 / Frequency

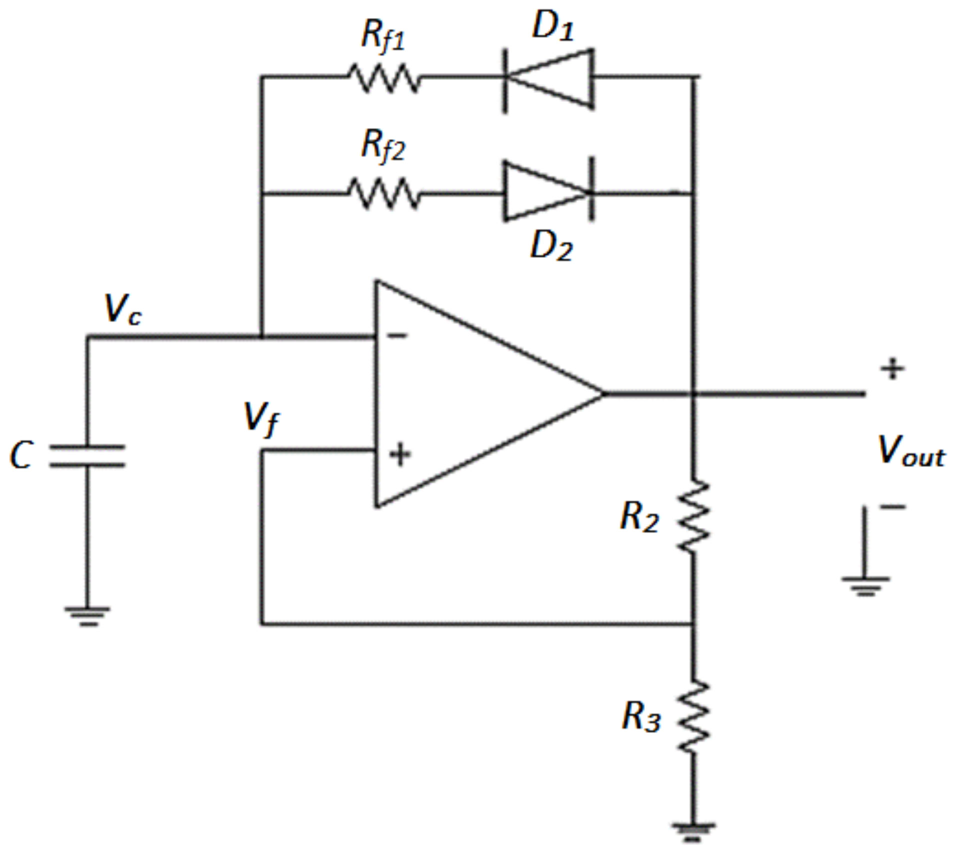
Period = $T_{on} + T_{off}$

Duty Cycle = $T_{on} / (T_{on} + T_{off}) * 100$

(On Percentage)



Assymmetrical Astable Multivibrator using OpAmp



❖ When, $V_{out} = +V_{sat}$; D_1 FB and D_2 RB.
C charges through R_{f1}
Charging time constant, $\tau_c = R_{f1}C$

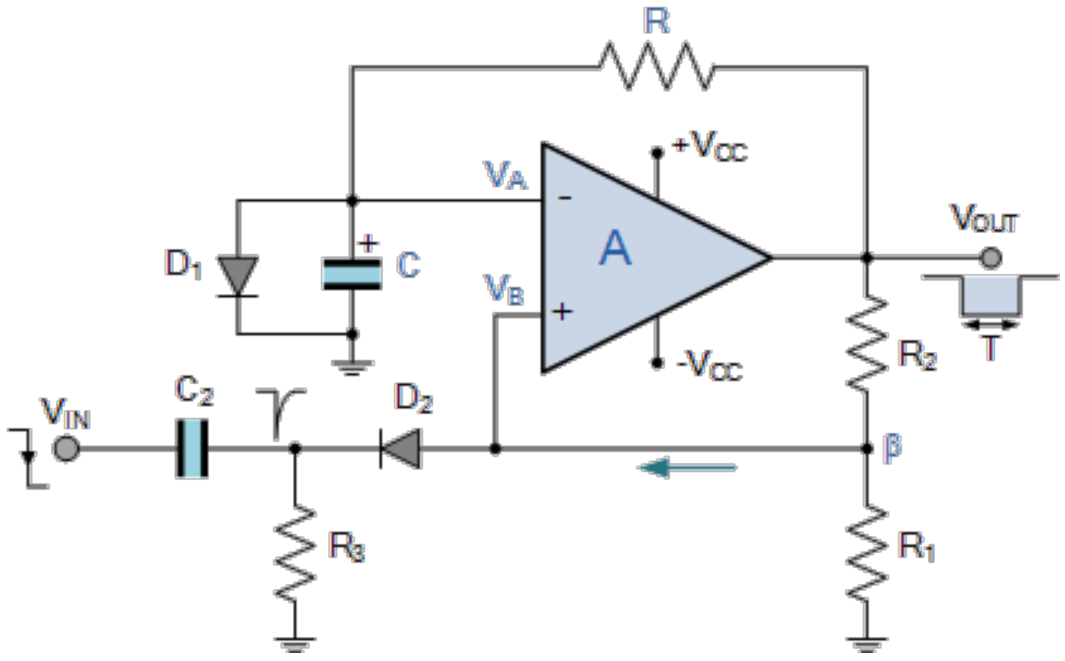
❖ When, $V_{out} = -V_{sat}$; D_1 RB and D_2 FB.
C dis-charges through R_{f2}
Dis-charging time constant, $\tau_d = R_{f2}C$

❖ If $R_{f1} \neq R_{f2}$; the rise time and fall time is not equal. Thus, the duty cycle is not 50%

Monostable Multivibrator

- ✓ The **monostable multivibrator** is also called **the one-shot multivibrator**.
- ✓ The circuit produces a single pulse of specified duration in response to each **external trigger** signal.
- ✓ For such a circuit, only one **stable state** exists.
- ✓ When an external trigger is applied, the output changes its state. The new state is called **a quasi-stable state**.
- ✓ The circuit remains in this state for a fixed interval of time. After some time it returns back to its original stable state.

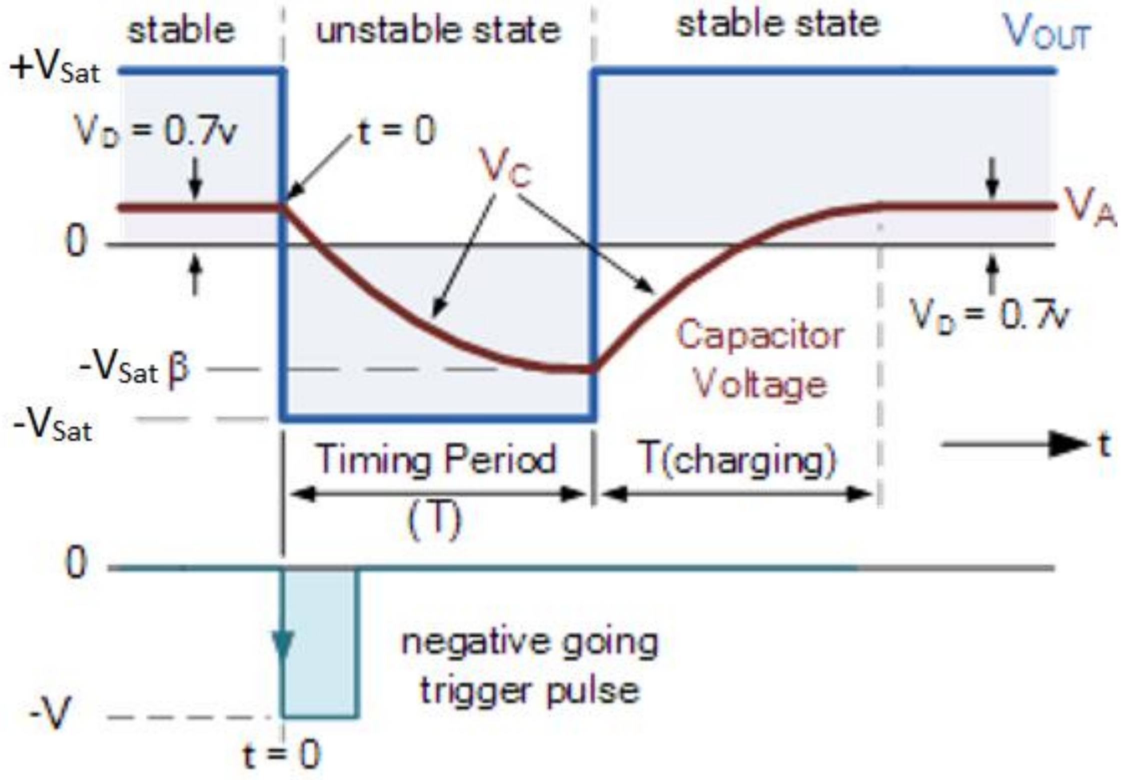
Monostable Multivibrator using Op-Amp



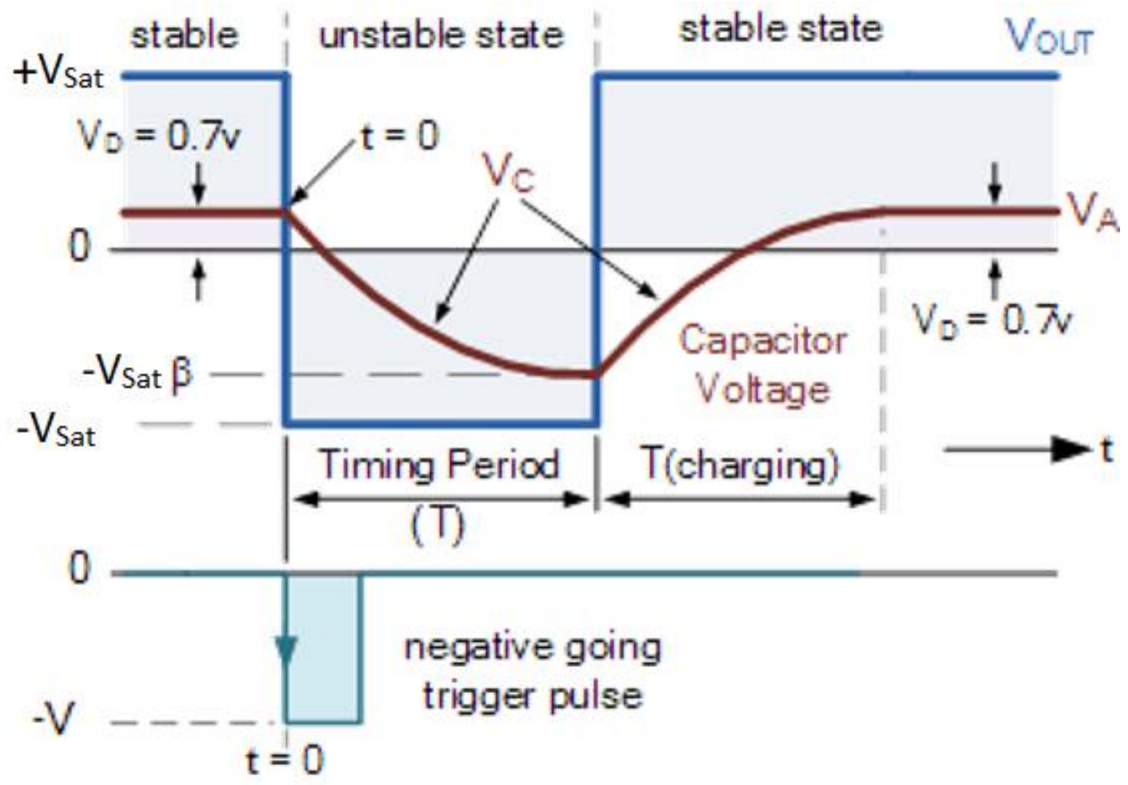
$$\beta = \frac{R_1}{R_1 + R_2}$$

$$V_{UT} = +\beta V_{Sat}$$

$$V_{LT} = -\beta V_{Sat}$$



Monostable Multivibrator using Op-Amp



Monostable Timing Period:

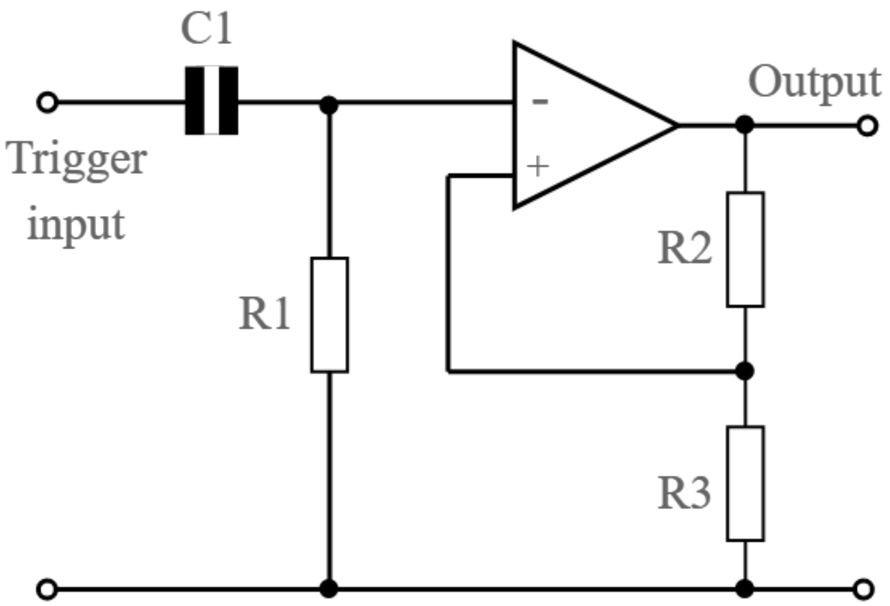
$$T = RC \ln\left(\frac{1 + \frac{V_D}{V_{Sat}}}{1 - \beta}\right)$$

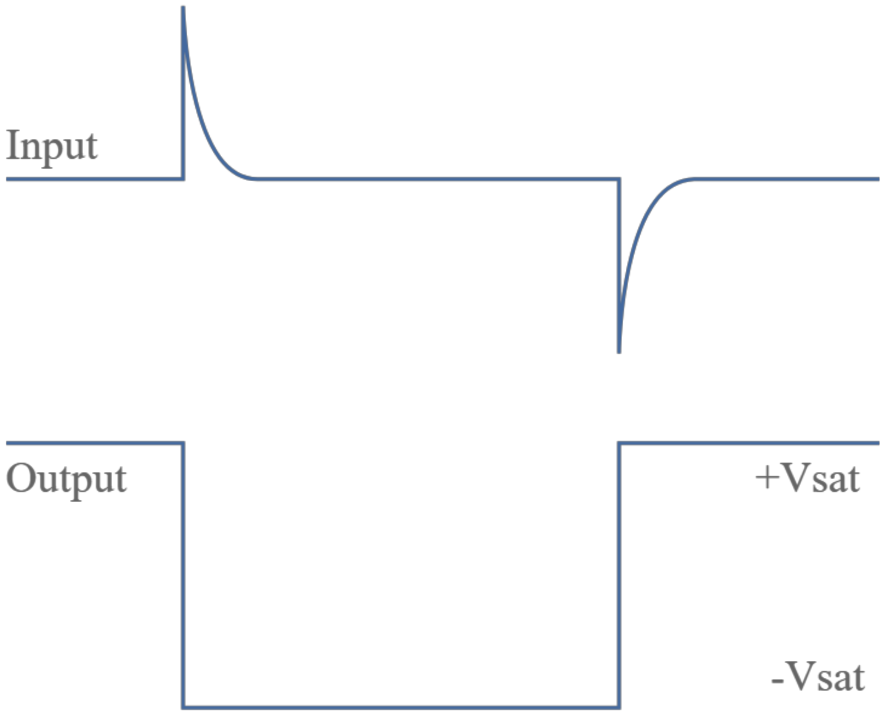
$$T = RC \ln\left(1 + \frac{R_1}{R_2}\right) \quad \text{[if, } V_D = 0V\text{]}$$

Bistable Multivibrator

- ✓ Bistable Multivibrators have TWO stable states (hence the name: "Bi") and maintain a given output state indefinitely unless an external trigger is applied forcing it to change state.
- ✓ The Bistable multivibrator can be switched over from one stable state to the other by the application of an external trigger pulse thus, it requires two external trigger pulses before it returns back to its original state.
- ✓ As Bistable multivibrators have two stable states they are more commonly used as Latches and Flip-flops for use in sequential type circuits

Bi-stable Multivibrator using Op-Amp





In this circuit, both the states at the output (+Vsat and -Vsat) are stable states. *i.e.* the circuit remains in the same state till the external input is applied. If we want to change the output state a triggering pulse is applied. Now the state obtained after the pulse is applied, is a permanent stable state. If we want to change the state again, we have to apply another triggering pulse. Thus, by only application of trigger pulse, output changes its state. Thus, to get the original state back, two triggering pulses need to be applied.

Triangle-Wave Generator using OpAmp

- Self Study from:

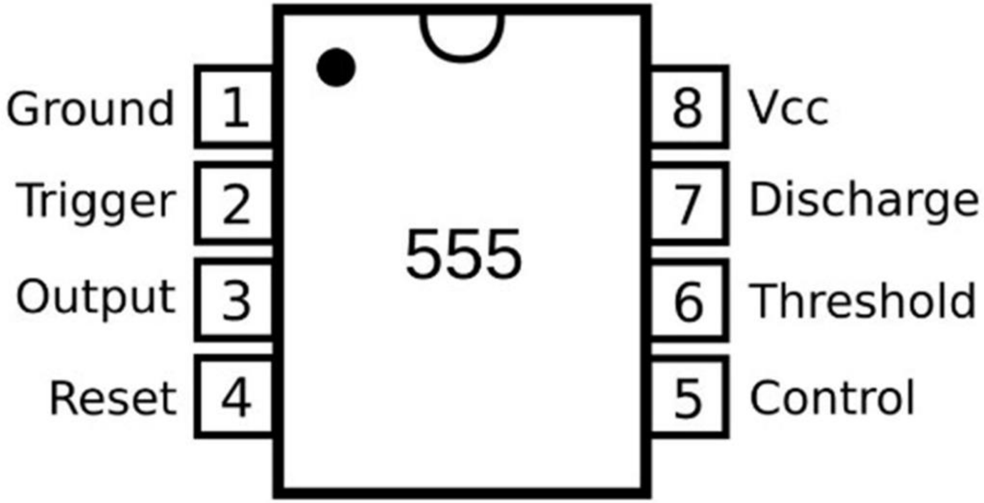
  Operational Amplifiers and Linear Integrated Circuits

  – Robert F. Coughlin, Frederick F. Driscoll – Prentice Hall (6th Edition)

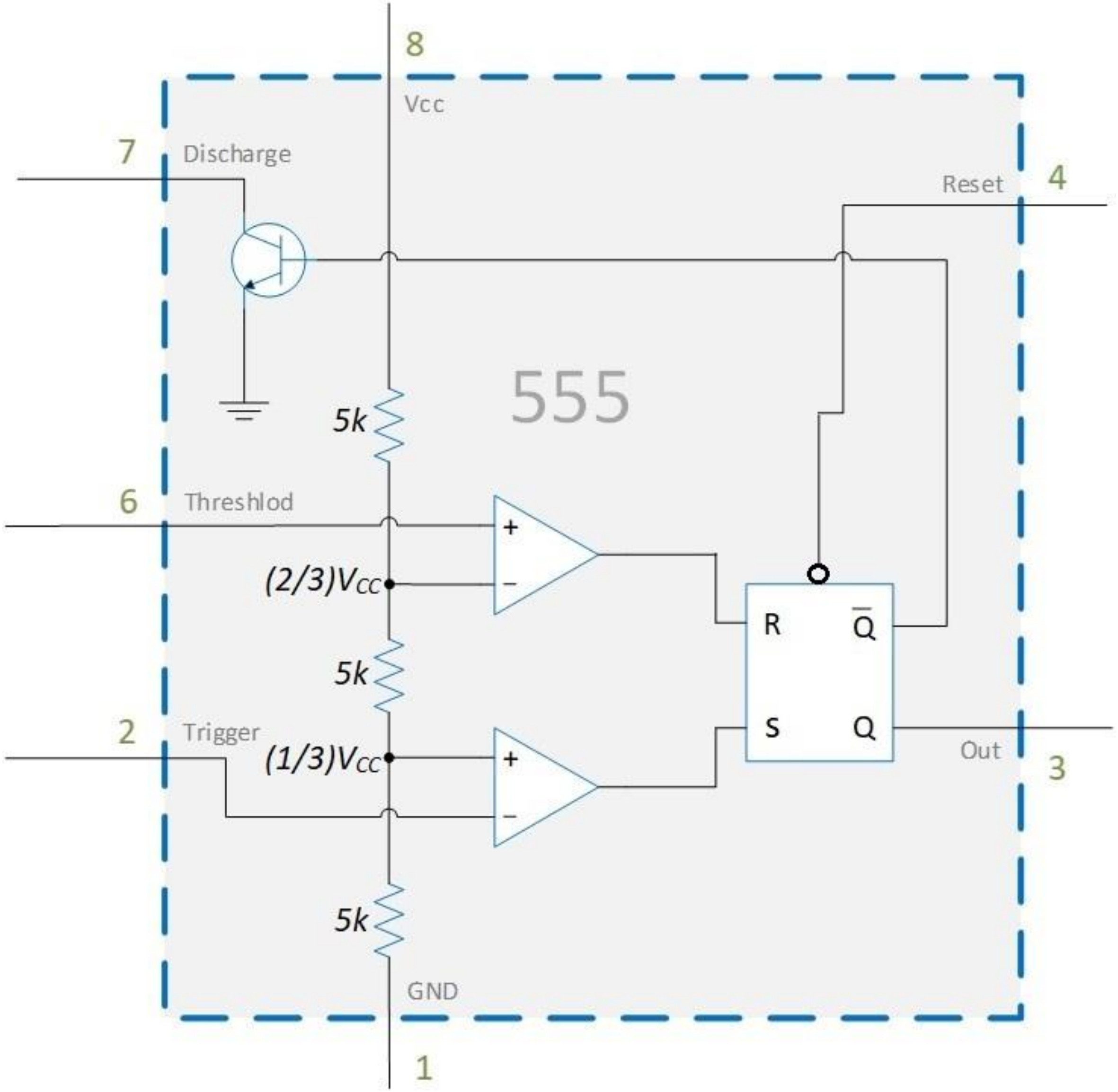
  Article: 6.3

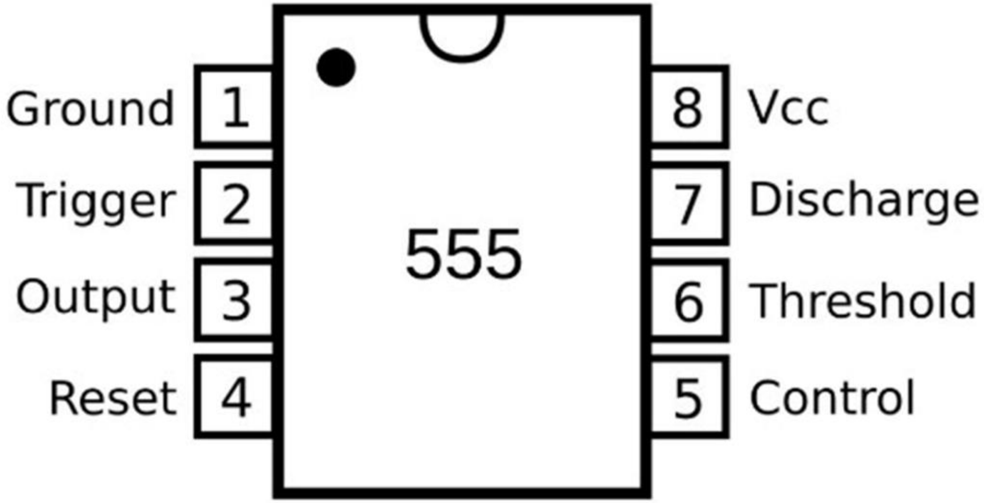
555 Timer IC

- The 555 timer is an 8-pin IC that is capable of producing accurate time delays and/or oscillators.
- In the time delay mode, the delay is controlled by one external resistor and capacitor.
- In the oscillator mode, the frequency of oscillation and duty cycle are both controlled with two external resistors and one capacitor.
- In general, 555 can operate from a supply voltage between 4.5 volts and 16 volts approx., with its output voltage slightly lower than its supply voltage Vcc. (depends on IC logic family)
- The name "555" comes from the fact that three 5k ohm resistors in series configuration can be found in its internal structure.

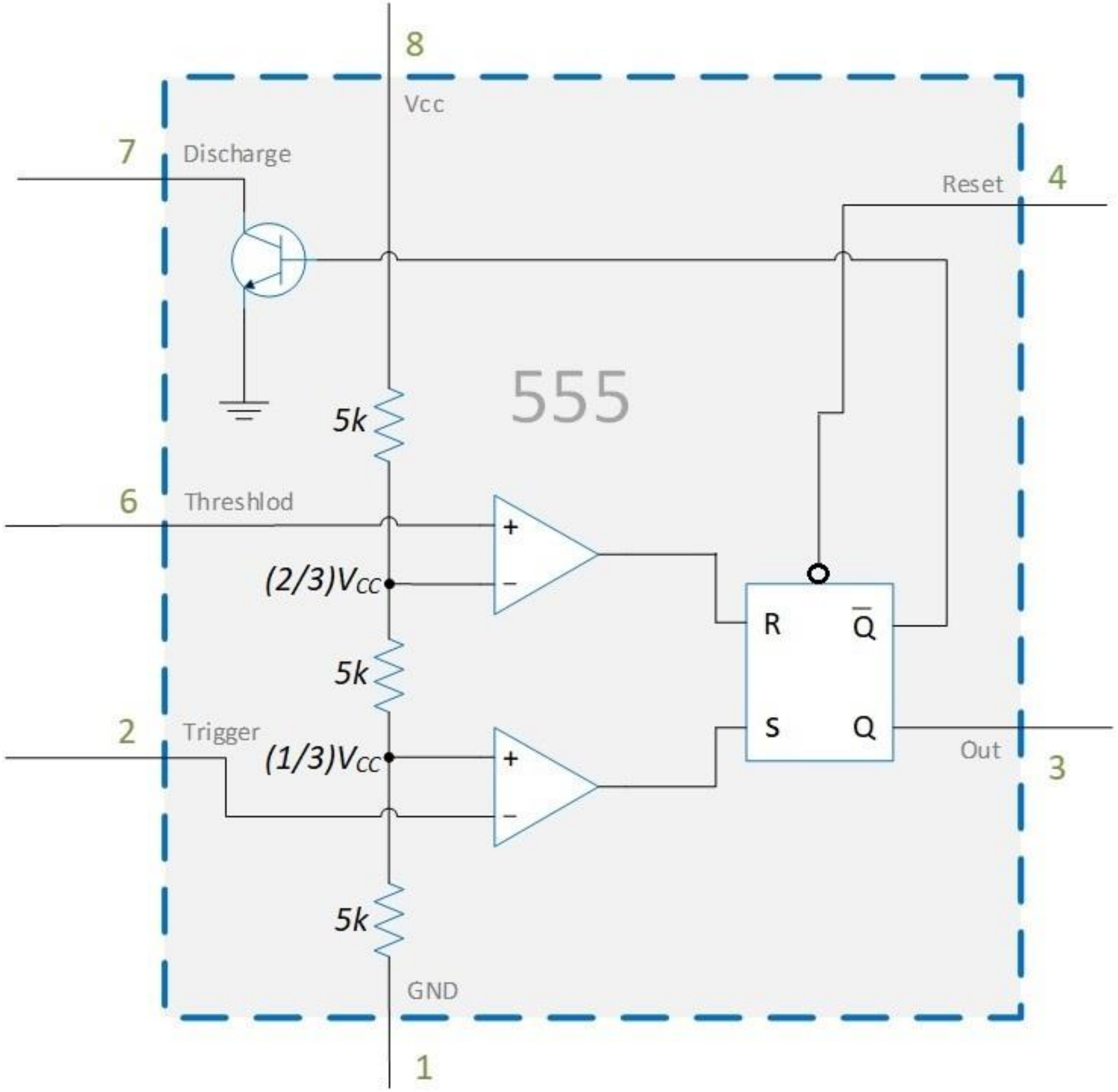


555 Timer IC: Internal Construction

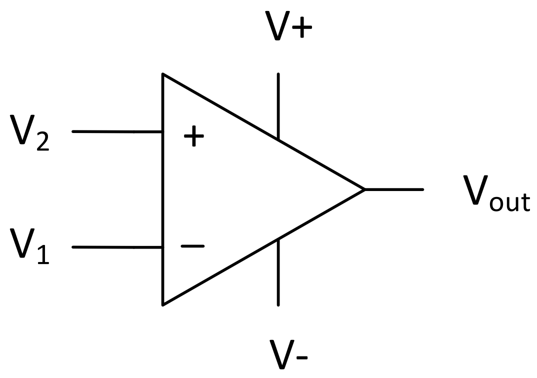




555 Timer IC: Internal Construction



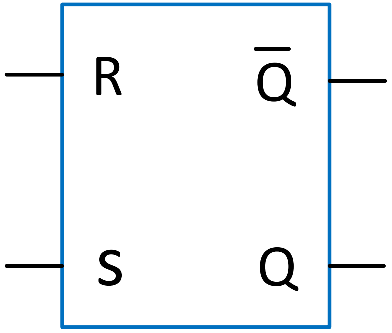
Op Amp as Comparator



$V_2 > V_1 : V_{out} = + V_{Sat}$

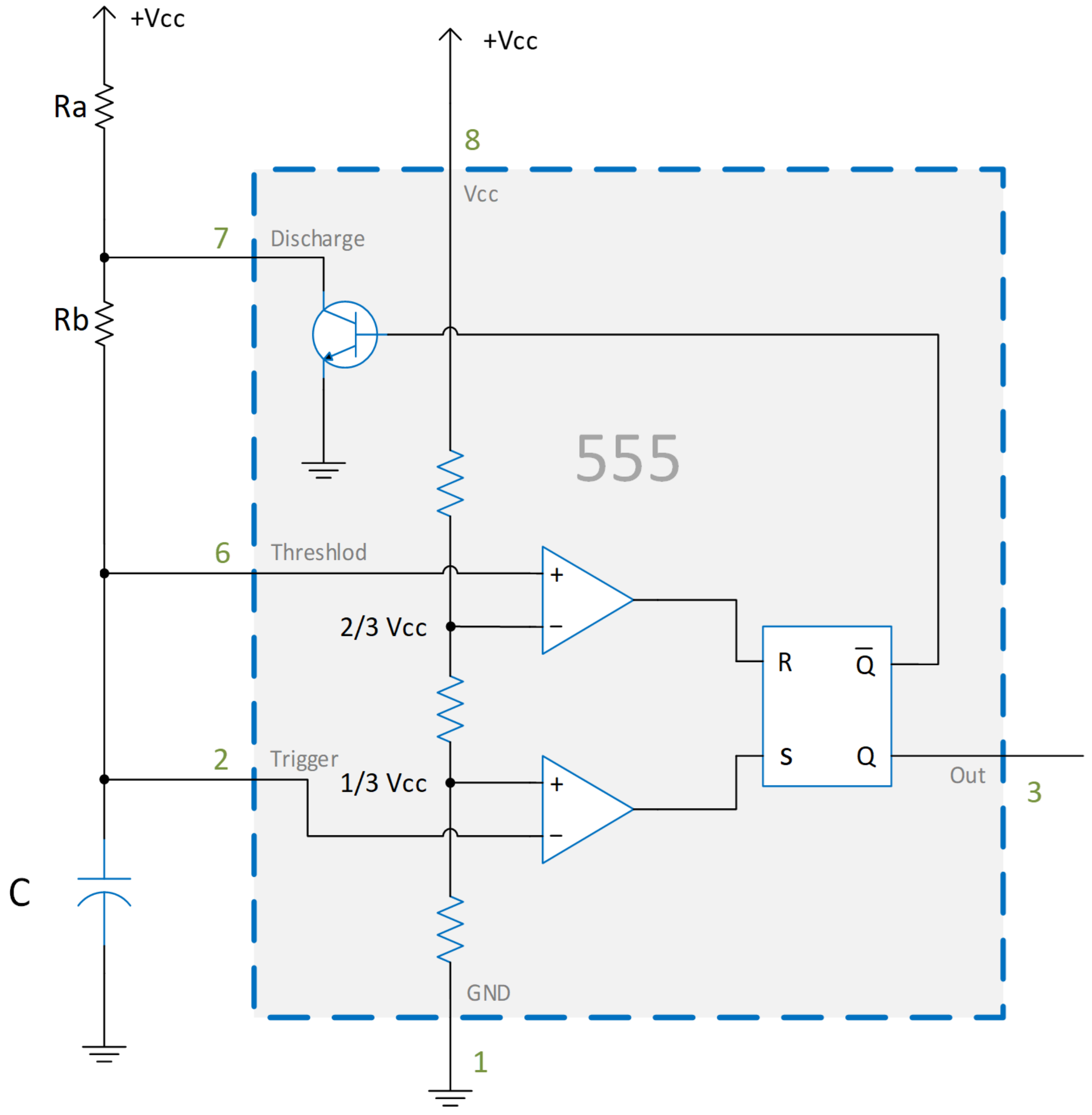
$V_2 < V_1 : V_{out} = - V_{Sat}$

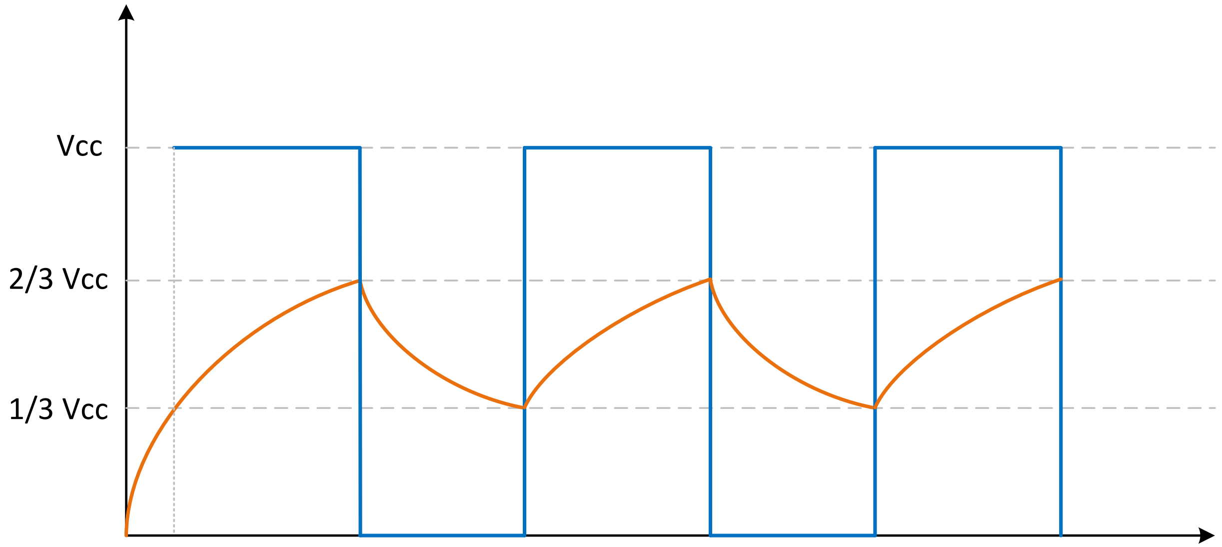
SR Latch



S	R	Q	State
0	0	Prev. State	No Change
1	0	1	Set
0	1	0	Reset
1	1	?	Forbidden

Astable Multivibrator using 555 Timer





Calculating Total Period and Duty Cycle

t_{HIGH} : Calculations for the Oscillator's HIGH Time

$$V_C = V_{Final} + \left(V_{Initial} - V_{Final}\right) \times \left(e^{\frac{-t}{RC}} \right)$$

$$\tfrac{2}{3} V_{CC} = V_{CC} + \left(\tfrac{1}{3} V_{CC} - V_{CC}\right) \times \left(e^{\frac{-t}{RC}} \right)$$

$$-\tfrac{1}{3} V_{CC} = \left(-\tfrac{2}{3} V_{CC}\right) \times \left(e^{\frac{-t}{RC}} \right)$$

$$\tfrac{1}{2} = \left(e^{\frac{-t}{RC}} \right)$$

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

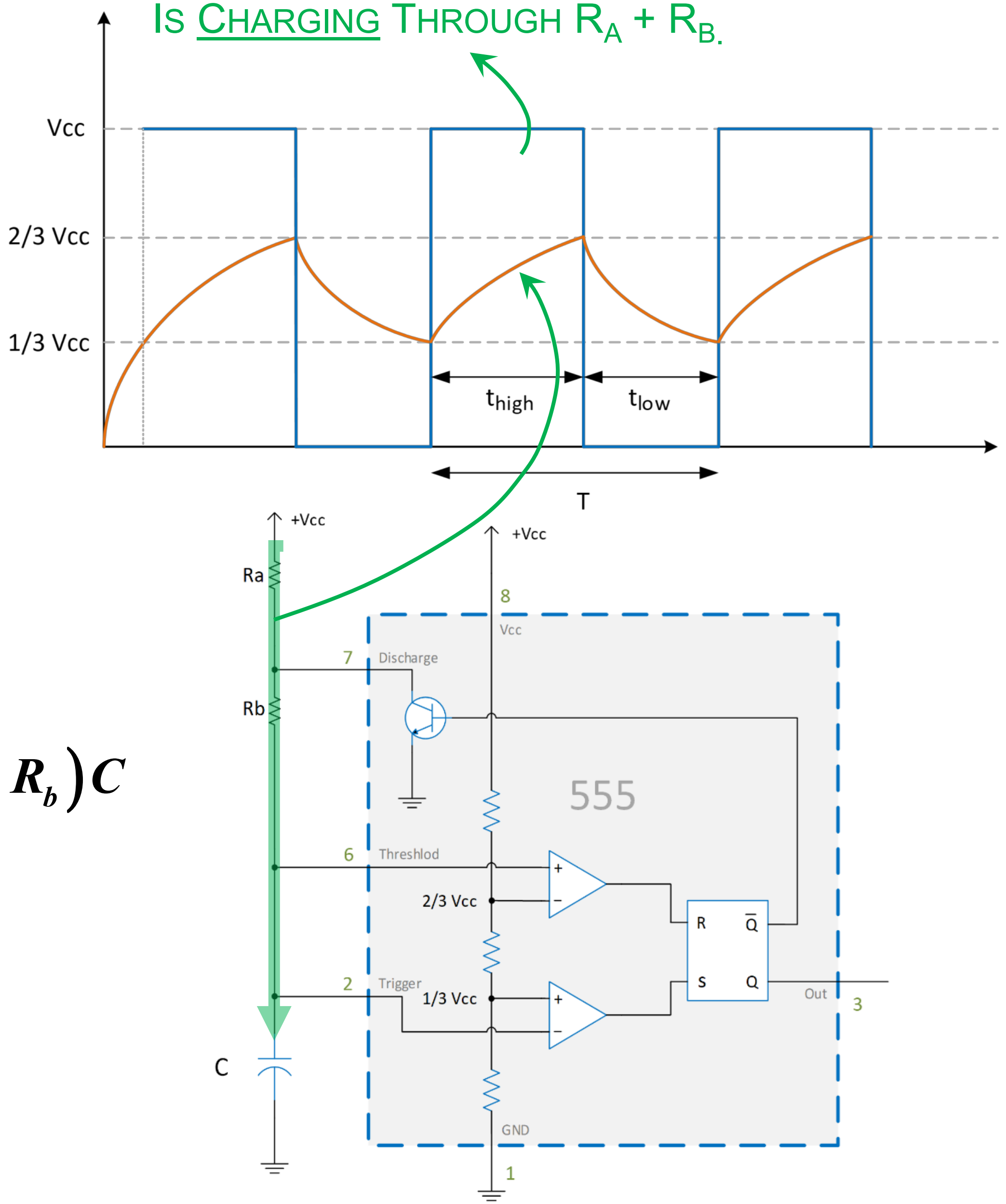
$$\ln\left(\tfrac{1}{2}\right) = \ln\left(e^{\frac{-t}{RC}} \right)$$

$$-0.693 = -\frac{t}{RC}$$

$$t = 0.693\ R\ C$$

$$t_{HIGH} = 0.693\left(R_a + R_b\right) C$$

THE OUTPUT IS HIGH WHILE THE CAPACITOR IS CHARGING THROUGH R_A + R_B.



Calculating Total Period and Duty Cycle

t_{LOW}: Calculations for the Oscillator's LOW Time

$$V_C = V_{Final} + \left(V_{Initial} - V_{Final}\right) \times \left(e^{\frac{-t}{RC}}\right)$$

$$\tfrac{1}{3}V_{CC} = 0 + \left(\tfrac{2}{3}V_{CC} - 0\right) \times \left(e^{\frac{-t}{RC}}\right)$$

$$\tfrac{1}{3}V_{CC} = \left(\tfrac{2}{3}V_{CC}\right) \times \left(e^{\frac{-t}{RC}}\right)$$

$$\frac{\tfrac{1}{3}V_{CC}}{\tfrac{2}{3}V_{CC}} = \left(e^{\frac{-t}{RC}}\right)$$

$$\tfrac{1}{2} = \left(e^{\frac{-t}{RC}}\right)$$

$$\tfrac{1}{2} = \left(e^{\frac{-t}{RC}}\right)$$

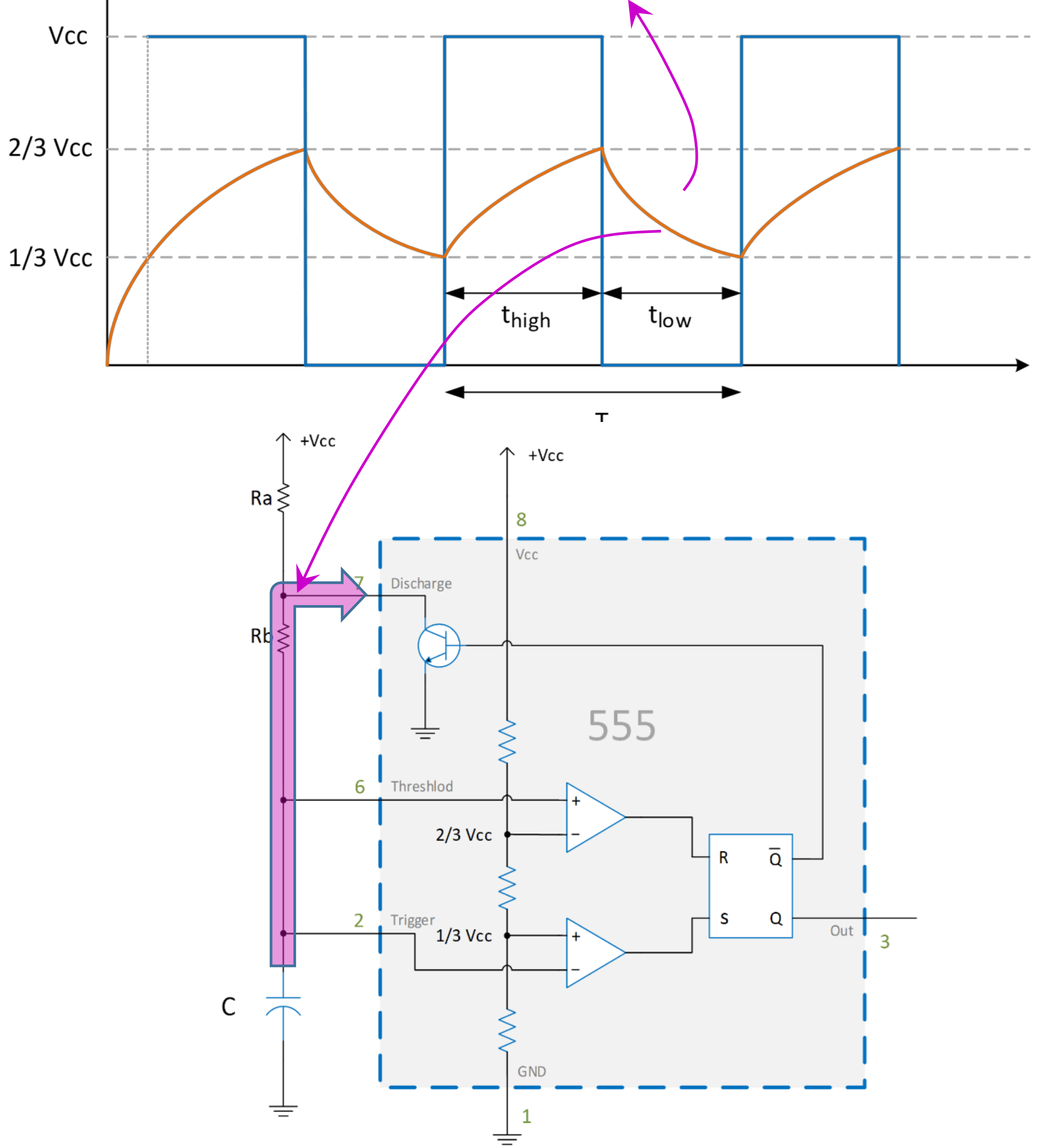
$$\ln\left(\tfrac{1}{2}\right) = \ln\left(e^{\frac{-t}{RC}}\right)$$

$$-0.693 = -\frac{\mathrm{t}}{RC}$$

$$t = 0.693\ RC$$

$$t_{LOW} = 0.693\ R_b C$$

THE OUTPUT IS <u>LOW</u> WHILE THE CAPACITOR IS <u>DISCHARGING</u> THROUGH R_B.



Calculating Total Period and Duty Cycle

$t_{high} = 0.693\,(R_a + R_b)\,C$

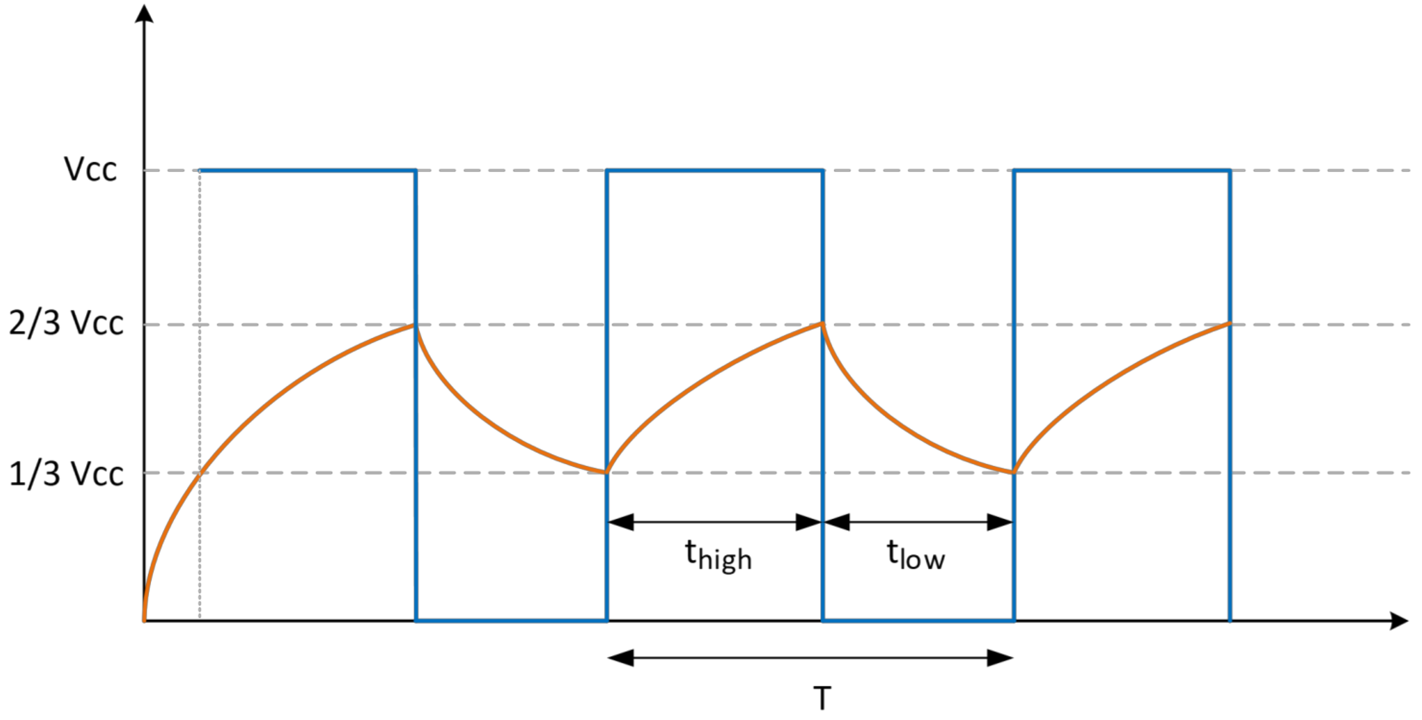
$t_{low} = 0.693\,(R_b)\,C$

Total period, $T = t_{high} + t_{low}$

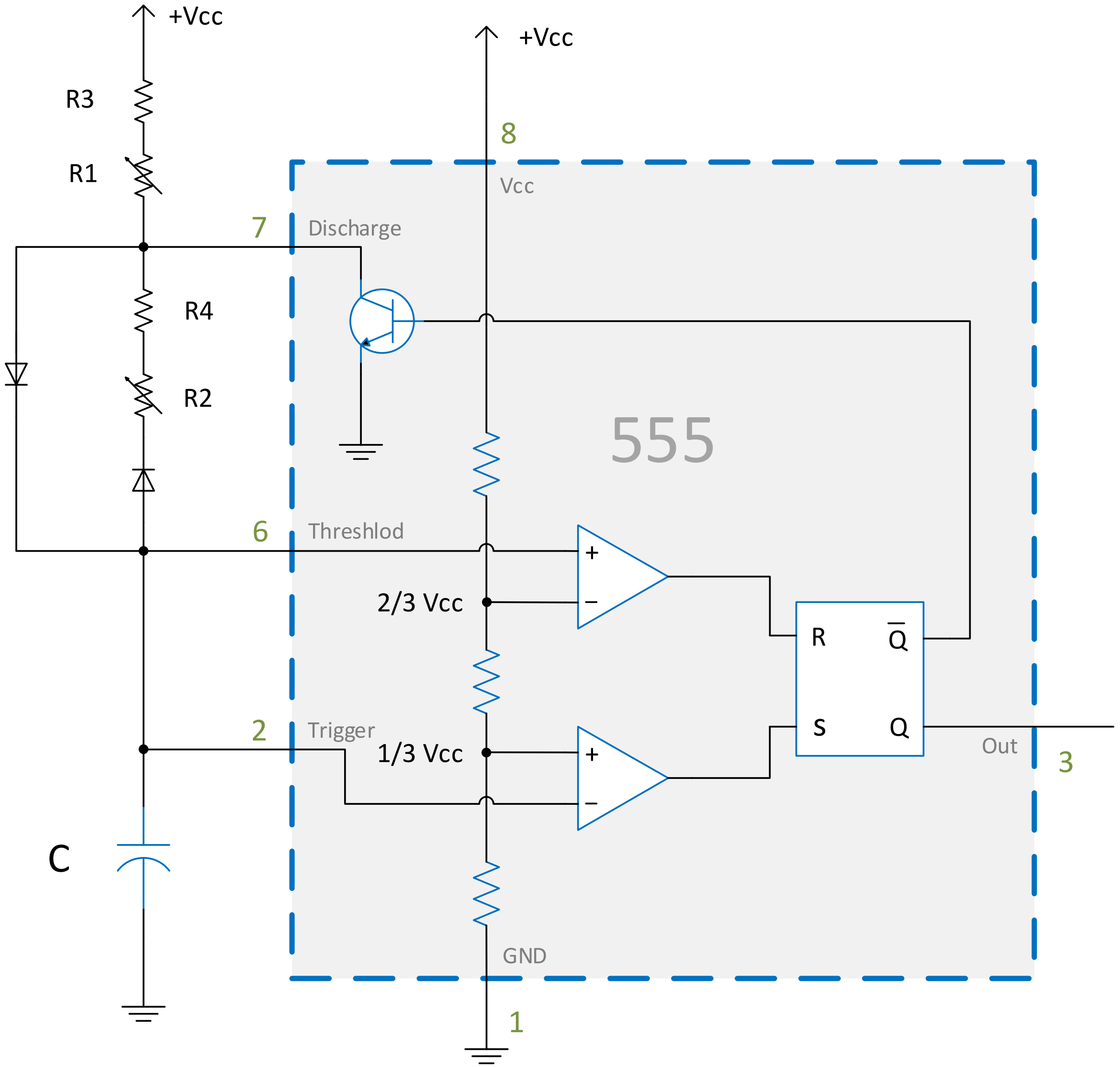
$= 0.693\,(R_a + 2R_b)\,C$

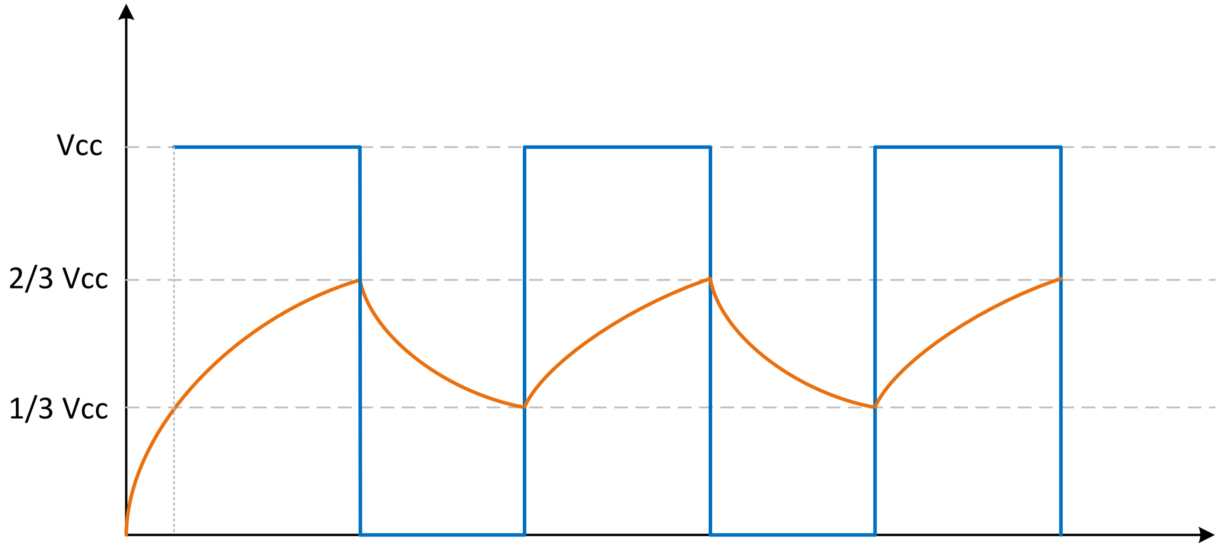
Duty cycle, $D = \dfrac{t_{high}}{T}$

$= \dfrac{R_a + R_b}{R_a + 2Rb}$



Modified Design of Astable Multivibrator using 555 Timer





Calculating Total Period and Duty Cycle

$t_{high} = 0.693\,(R_1 + R_3)\,C$

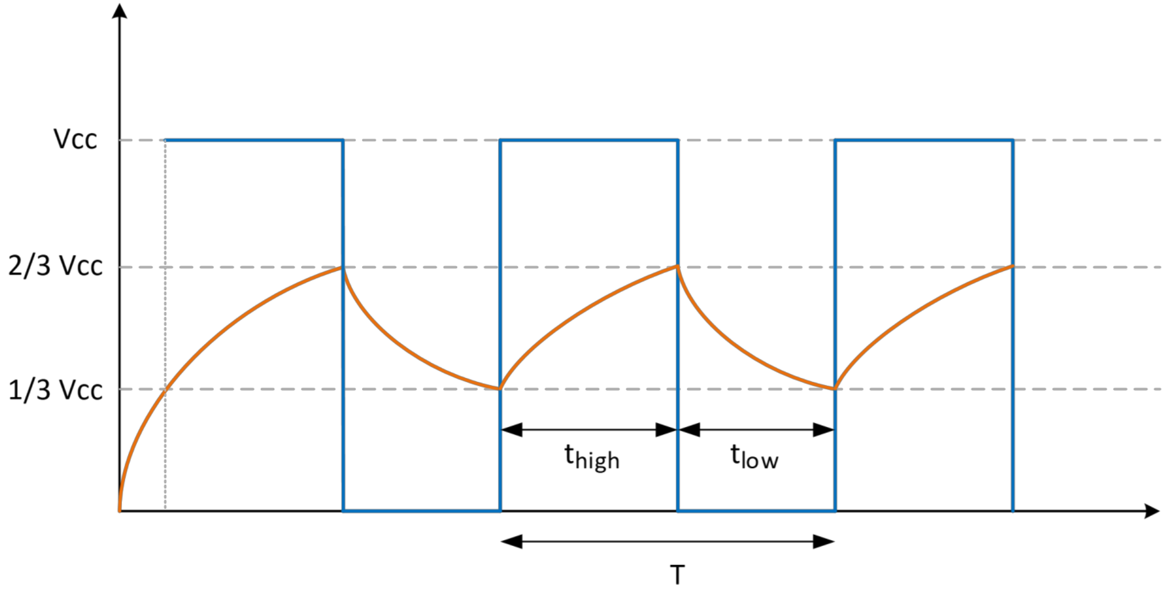
$t_{low} = 0.693\,(R_2 + R_4)\,C$

Total period, $T = t_{high} + t_{low}$

$= 0.693\,(R_1 + R_2 + R_3 + R_4)\,C$

Duty cycle, $D = \dfrac{t_{high}}{T}$

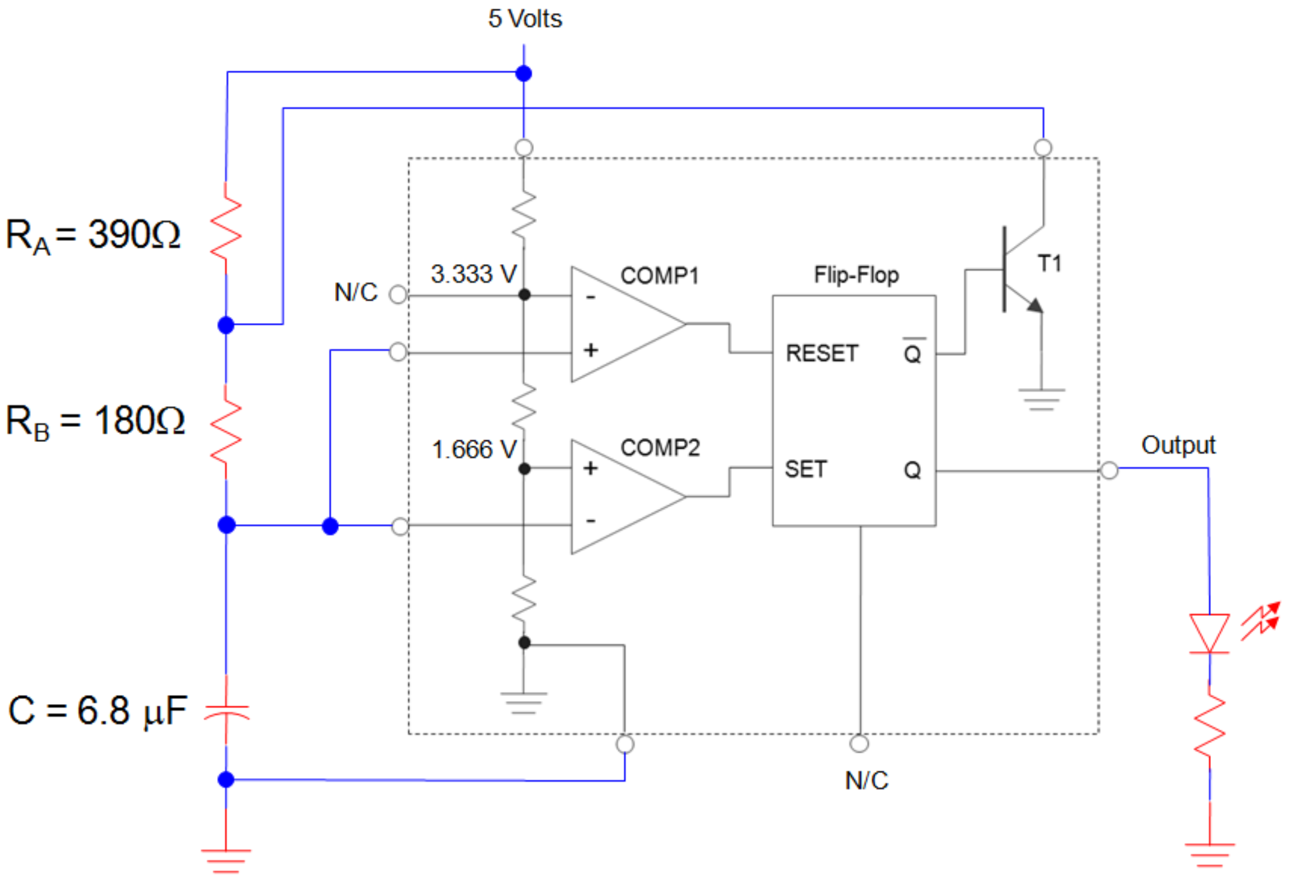
$= \dfrac{R1 + R3}{R1 + R2 + R3 + R4}$



Example

Example:

For the 555 Timer oscillator shown below, calculate the circuit's, period (T), frequency (F), and duty cycle (DC).



Example

Solution:

$$R_A = 390\ \Omega \qquad R_B = 180\ \Omega \qquad C = 6.8\ \mu F$$

Period:

$$T = 0.693\left(R_A + 2R_B\right)C$$

$$T = 0.693\left(390\Omega + 2\times 180\Omega\right)\times 6.8\mu F$$

$$\boxed{T = 3.534\,\text{mSec}}$$

Frequency:

$$F = \frac{1}{T}$$

$$F = \frac{1}{3.534\,\text{mSec}}$$

$$\boxed{F = 282.941\,\text{Hz}}$$

Duty Cycle:

$$DC = \frac{\left(R_A + R_B\right)}{\left(R_A + 2R_B\right)}\times 100\%$$

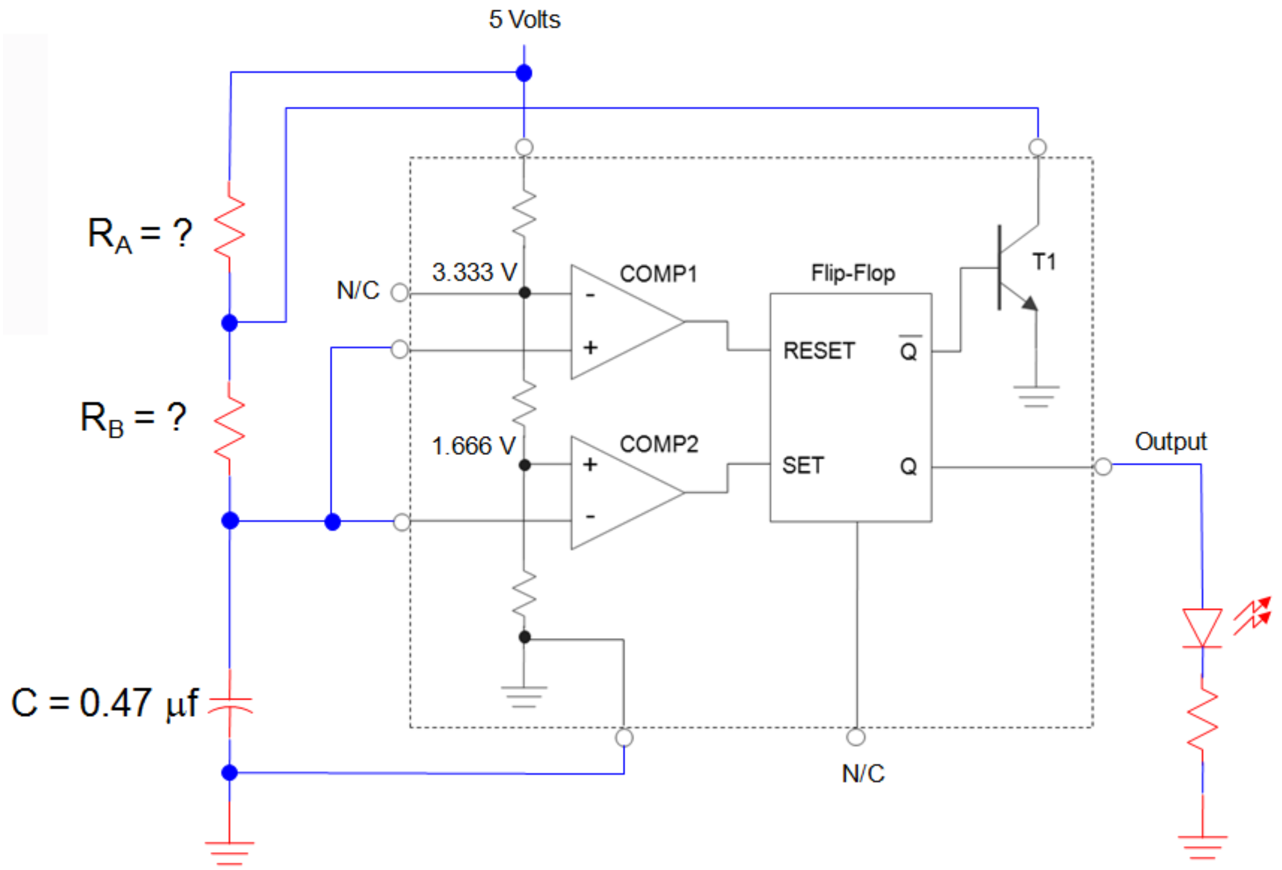
$$DC = \frac{\left(390\,\Omega + 180\,\Omega\right)}{\left(390\,\Omega + 2\times 180\,\Omega\right)}\times 100\%$$

$$\boxed{DC = 76\%}$$

Example

Example:

For the 555 Timer oscillator shown below, calculate the value for R_A & R_B so that the oscillator has a frequency of 2.5 KHz @ 60% duty cycle.



Example

Solution:

Frequency:

$$T = \frac{1}{f} = \frac{1}{2.5\,\text{kHz}} = 400\mu\text{Sec}$$

$$T = 0.693\,(R_A + 2R_B)\,C = 400\mu\text{Sec}$$

$$T = 0.693\,(R_A + 2R_B)\,0.47\mu f = 400\mu\text{Sec}$$

$$R_A + 2R_B = \frac{400\mu\text{Sec}}{0.693 \times 0.47\mu f} = 1228.09\,\Omega$$

$$R_A + 2R_B = 1228.09$$

Duty Cycle:

$$DC = \frac{(R_A + R_B)}{(R_A + 2R_B)} \times 100\% = 60\%$$

$$\frac{(R_A + R_B)}{(R_A + 2R_B)} = 0.6$$

$$R_A + R_B = 0.6(R_A + 2R_B)$$

$$R_A + R_B = 0.6 \times R_A + 1.2 \times R_B$$

$$0.4 \times R_A = 0.2 \times R_B$$

$$R_A = 0.5 \times R_B$$

Two Equations & Two Unknowns!

Example

Solution:

Frequency:

$$R_A + 2R_B = 1228.09$$

Duty Cycle:

$$R_A = 0.5 \times R_B$$

Substitute and Solve for R_B

$$R_A + 2R_B = 1228.09\,\Omega$$

$$0.5 \times R_B + 2R_B = 1228.09\,\Omega$$

$$2.5R_B = 1228.09\,\Omega$$

$$\boxed{R_B = 491.23\,\Omega}$$

Substitute and Solve for R_A

$$R_A + 2R_B = 1228.09\,\Omega$$

$$R_A + 2(491.23\,\Omega) = 1228.09\,\Omega$$

$$R_A + 982.472\,\Omega = 1228.09\,\Omega$$

$$\boxed{R_A = 245.618\,\Omega}$$

Monostable Multivibrator using 555 Timer

- Self Study from:

  Digital Fundamentals – Thomas L. Floyd – Prentice Hall (2007)

  Article: 7.6

  Pulse, Digital and Switching Waveforms – Jacob Millman, Herbert Taub, Suryaprakash Rao – McGraw Hill (3rd Edition)

  Article: 9.14