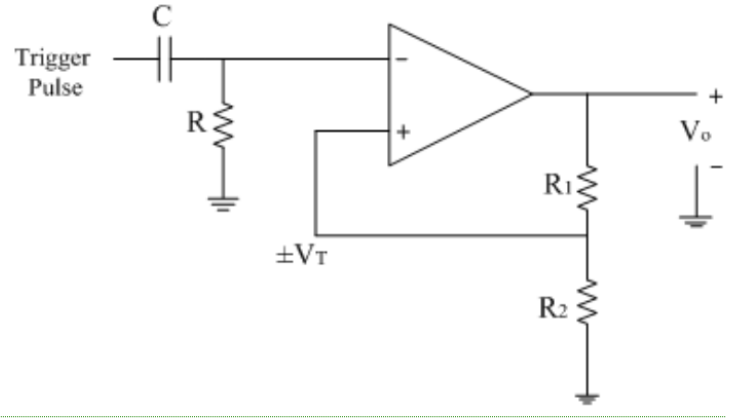
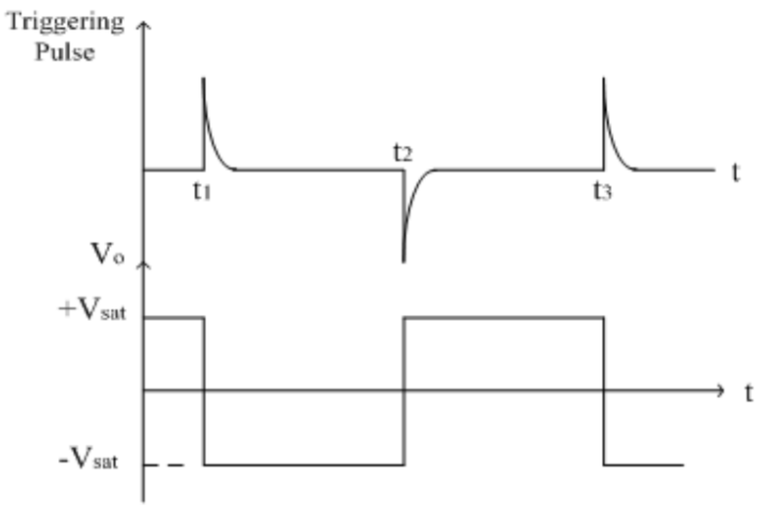
Islamic University of Technology

EEE 4483
Digital Electronics & Pulse Techniques

Lecture- 4

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 a 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.

Reference link: http://www.electronics-tutorial.net/analog-integrated-circuits/multivibrators/bistable-multivibrators/index.html

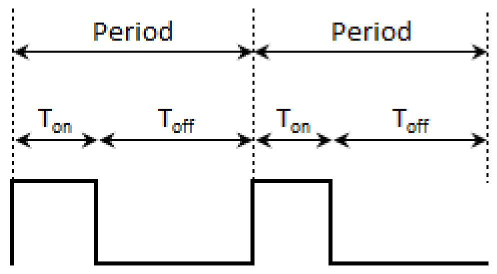
Duty Cycle

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.

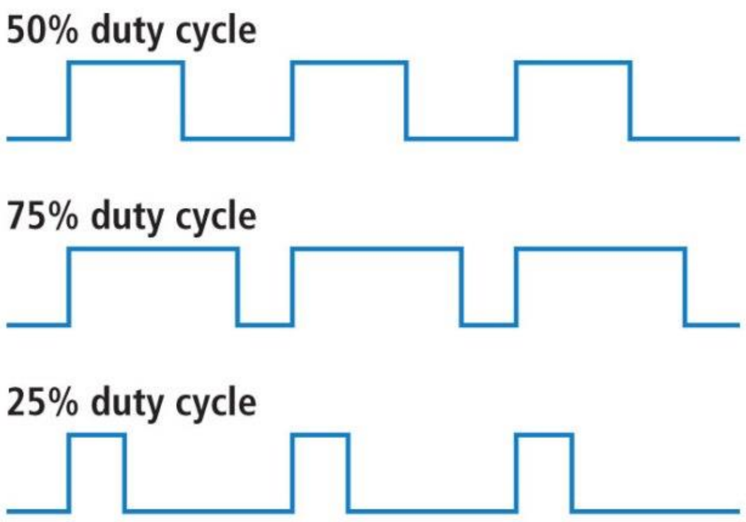


Period = 1 / Frequency

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

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

(On Percentage)

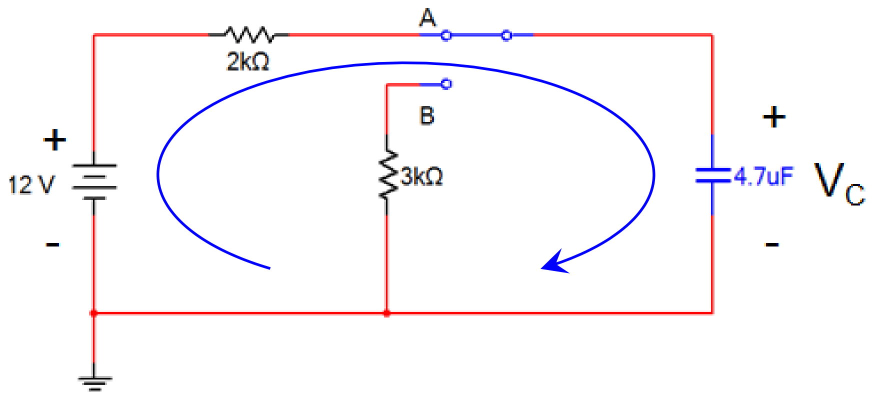


555: A Versatile Device

- The 555 Timer is one of the best known IC’s.
  - The 555 is part of every experimenter's tool kit

  - Capable of creating a wide variety of circuits, including:
    - Oscillators with adjustable frequency and Duty Cycle
    - Monostable Multivibrators
    - Analog to digital Converters
    - Frequency Meters
    - Many other applications….

Capacitor Charge Cycle



- Capacitor is initially discharged.
- Switch is moved to position A.
- Capacitor will charge to +12 v.
- Capacitor will charge through the 2 KΩ resistor.

<u>Equation for Charging Capacitor</u>

$$V_C = (V_{Final} - V_{Initial}) \times (1 - e^{-t/RC}) + V_{Initial}$$

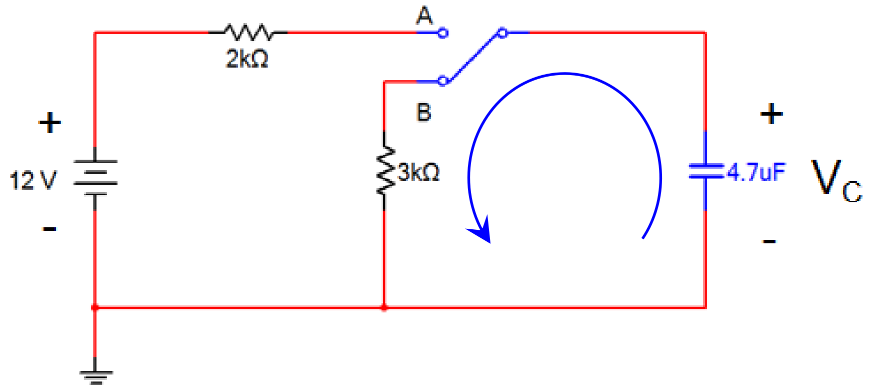
Where :

V_C = The voltage across the capacitor

V_{Final} = The voltage across the capacitor that is fully charged

$V_{Initial}$ = Any initial voltage across the capacitor as it begins to charge

Capacitor Discharge Cycle



- Capacitor is initially charged.
- Switch is moved to position B.
- Capacitor will discharge to +0 v.
- Capacitor will discharge through the 3 KΩ resistor.

Equation for Discharging Capacitor

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

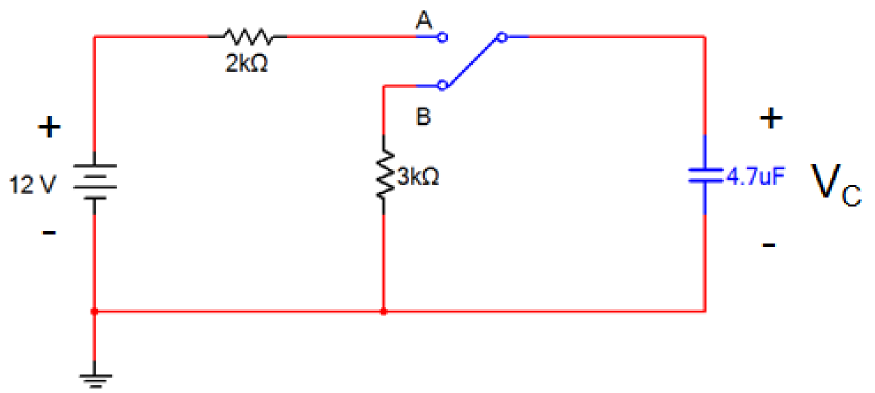
Where :

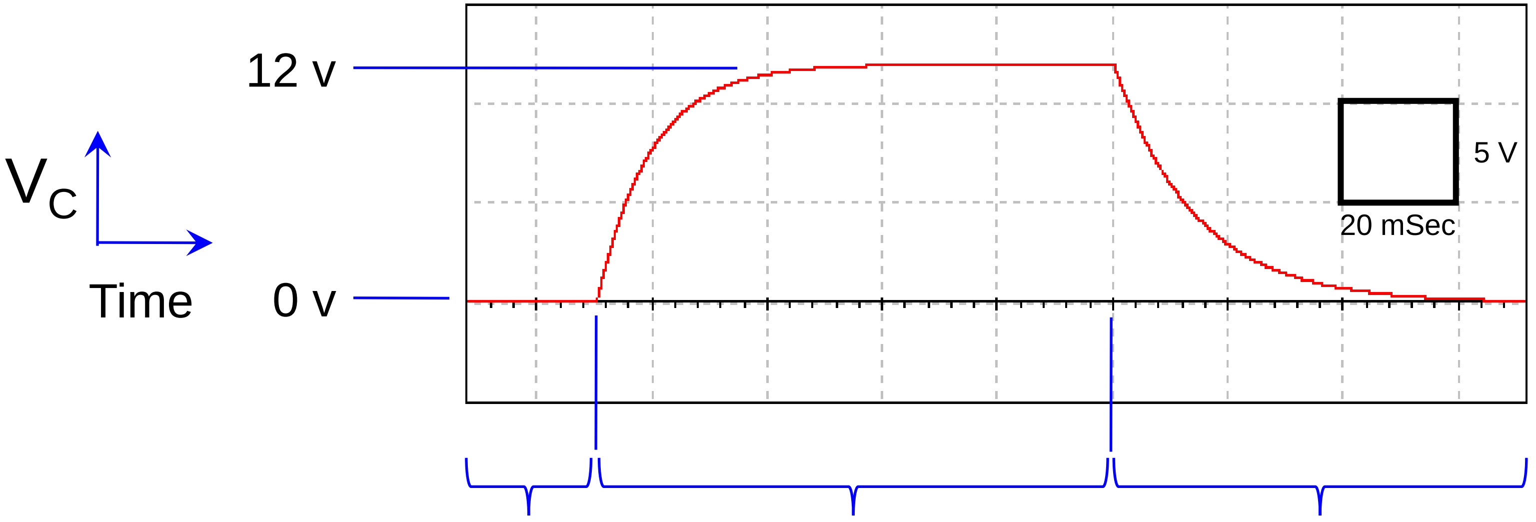
$V_C =$ The voltage across the capacitor

$V_{Final} =$ The voltage across the capacitor that is fully discharged

$V_{Initial} =$ Any initial voltage across the capacitor as it begins to discharge

Capacitor Charge & Discharge





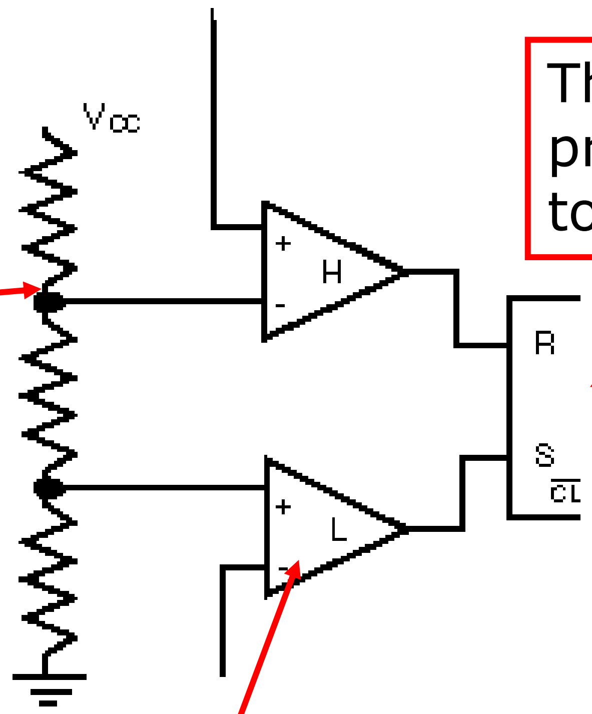
Switch has been at position B for a long period of time. The capacitor is completely discharged.

Switch is moved to position A. The capacitor charges through the 2KΩ resistor.

Switch is moved back to position B. The capacitor discharges through the 3KΩ resistors.

Reference and Comparators

A 3-resistor voltage divider provides reference voltages

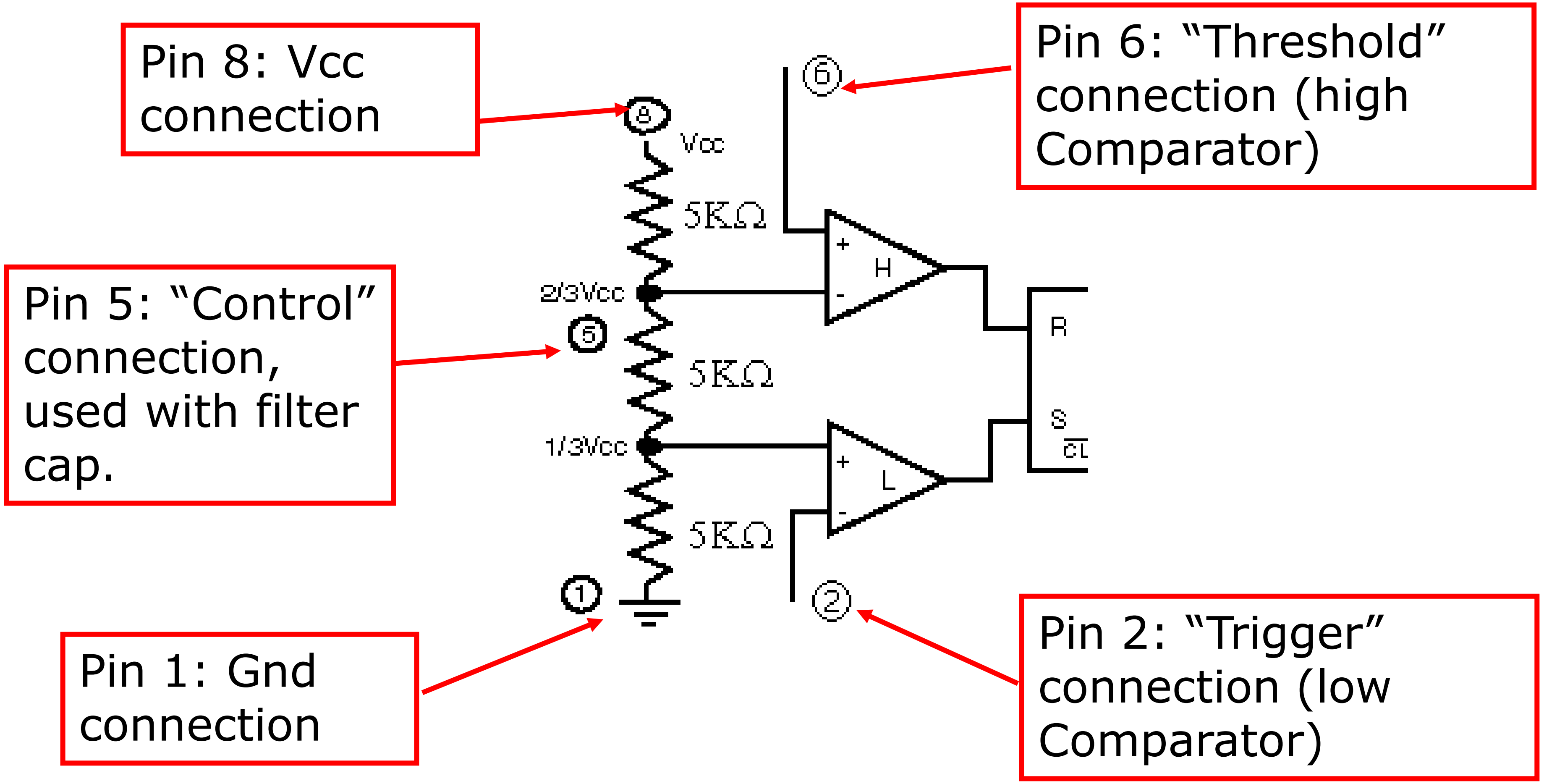


The Comparators provide digital logic to an SR Latch

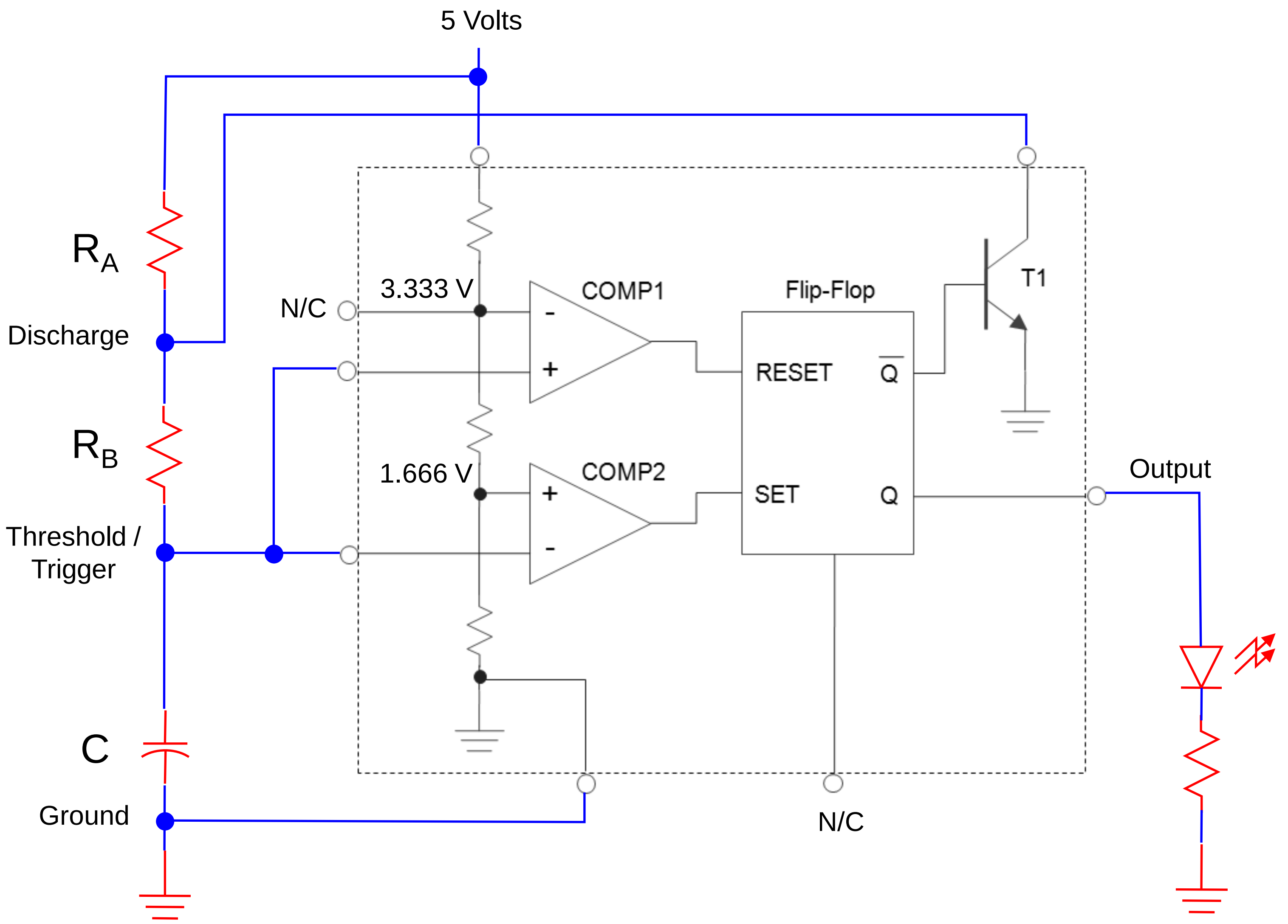
Comparators compare voltage levels.

- If "+" is higher, output = 1
- If "-" is higher, output = 0

Reference and Comparators: continued..

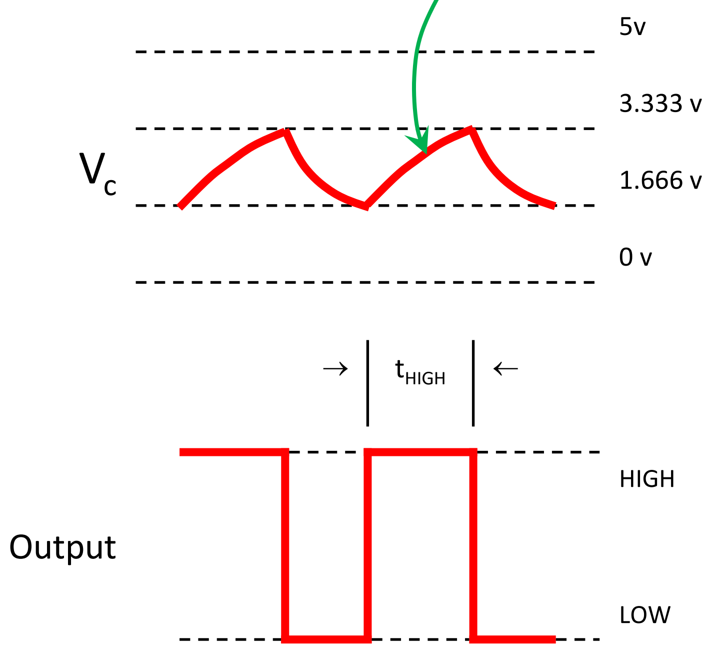


Schematic of a 555 Timer in Oscillator Mode

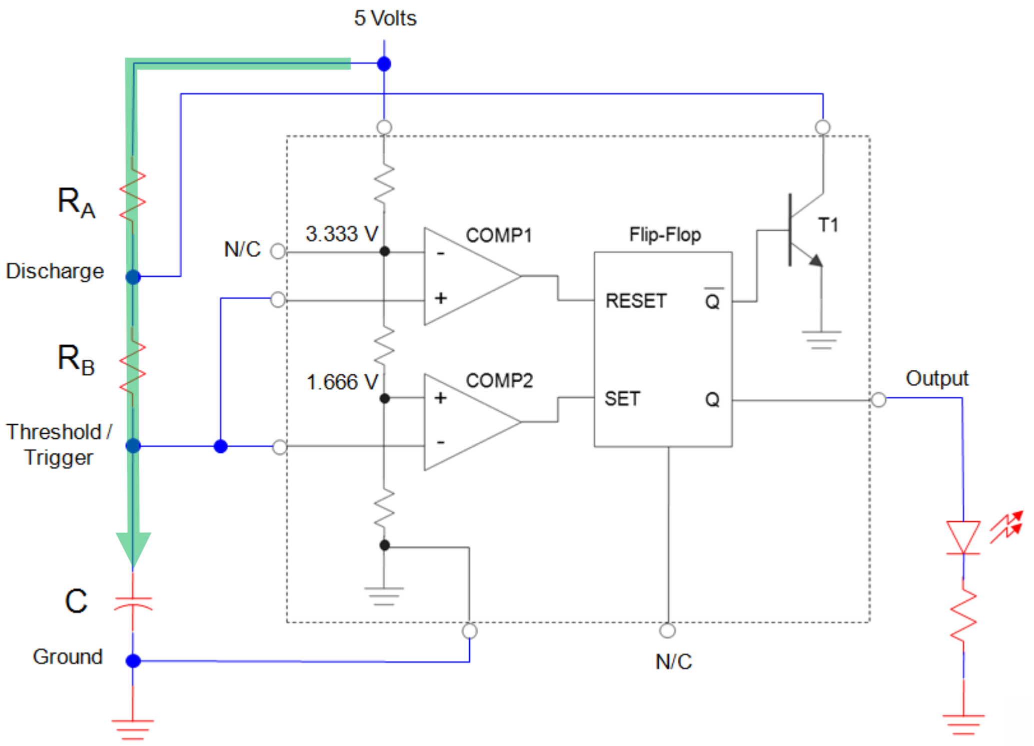


555 Timer Design Equations

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



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

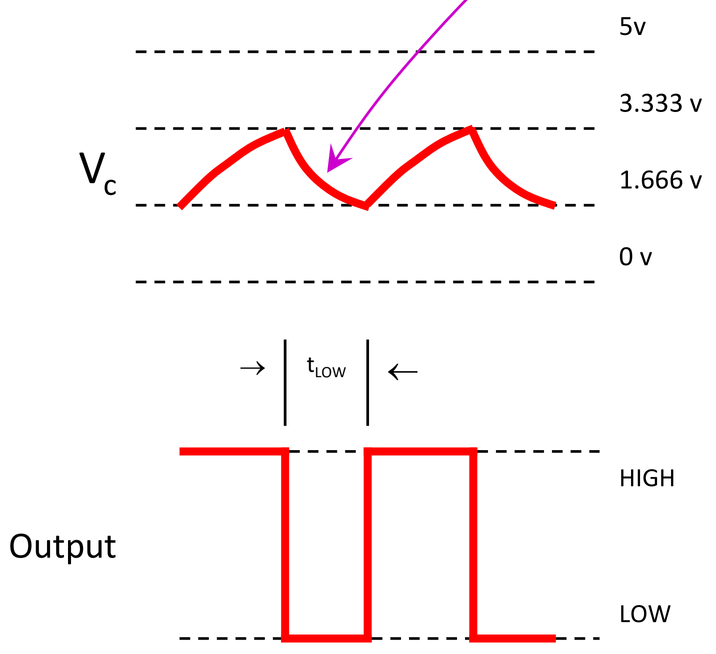


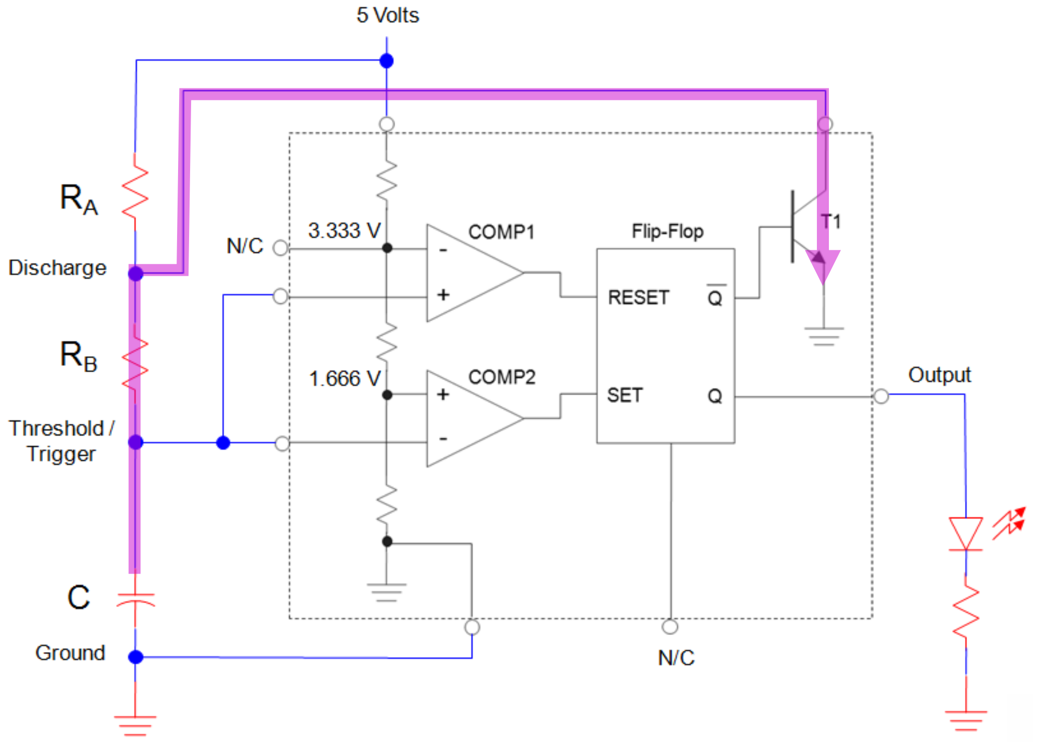
$$t_{HIGH} = 0.693(R_A + R_B)C$$

555 Timer Design Equations

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

The Output Is <u>LOW</u> While The Capacitor Is <u>Discharging</u> Through R_B.





$$t_{LOW} = 0.693 R_B C$$

555 Timer – Period / Frequency / DC

Period:

$$t_{HIGH} = 0.693\,(R_A + R_B)\,C$$

$$t_{LOW} = 0.693\,R_B C$$

$$T = t_{HIGH} + t_{LOW}$$

$$T = [0.693\,(R_A + R_B)\,C] + [0.693\,R_B C]$$

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

Duty Cycle:

$$DC = \frac{t_{HIGH}}{T} \times 100\%$$

$$DC = \frac{0.693\,(R_A + R_B)\,C}{0.693\,(R_A + 2R_B)\,C} \times 100\%$$

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

Frequency:

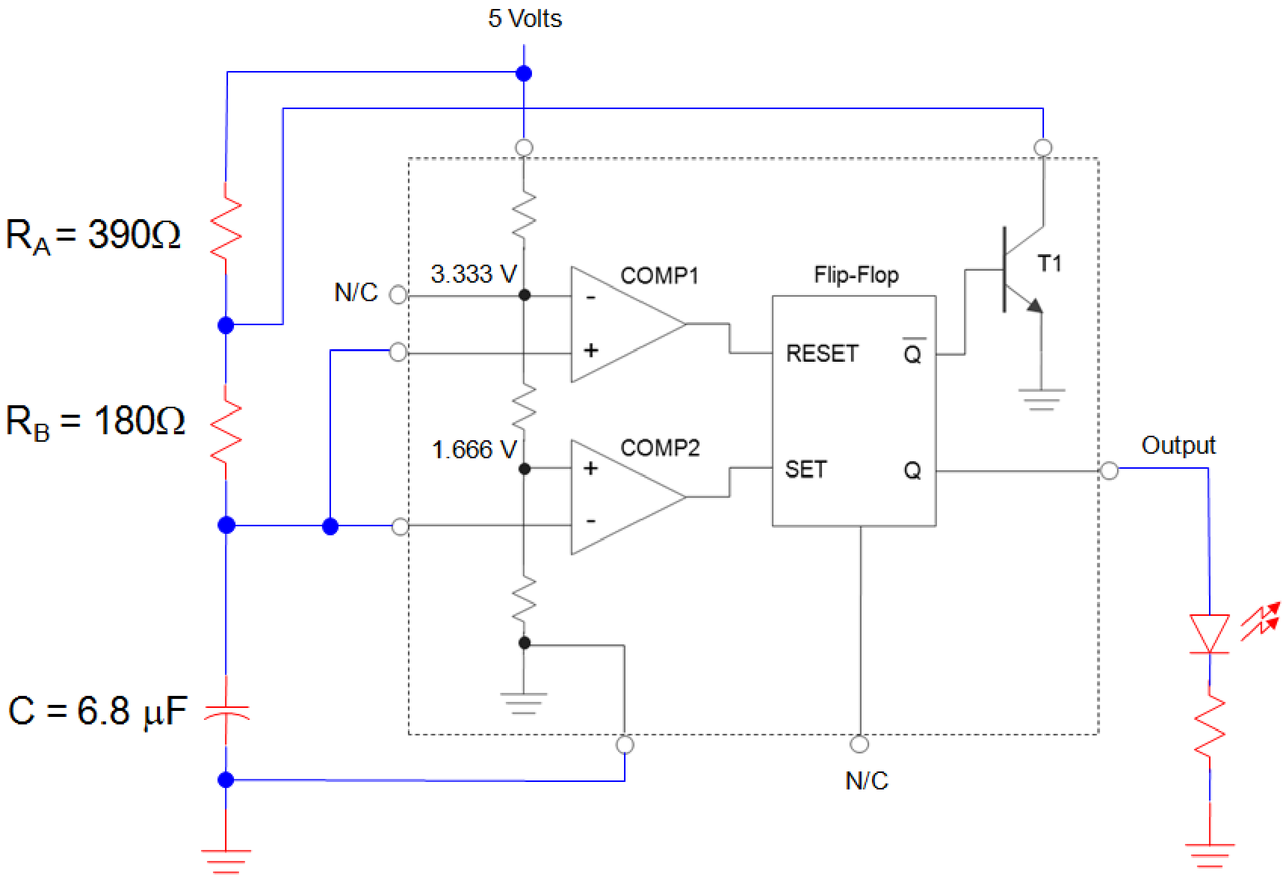
$$F = \frac{1}{T}$$

$$F = \frac{1}{0.693\,(R_A + 2R_B)\,C}$$

Example: 555 Oscillator

Example:

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



Example: 555 Oscillator

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:

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

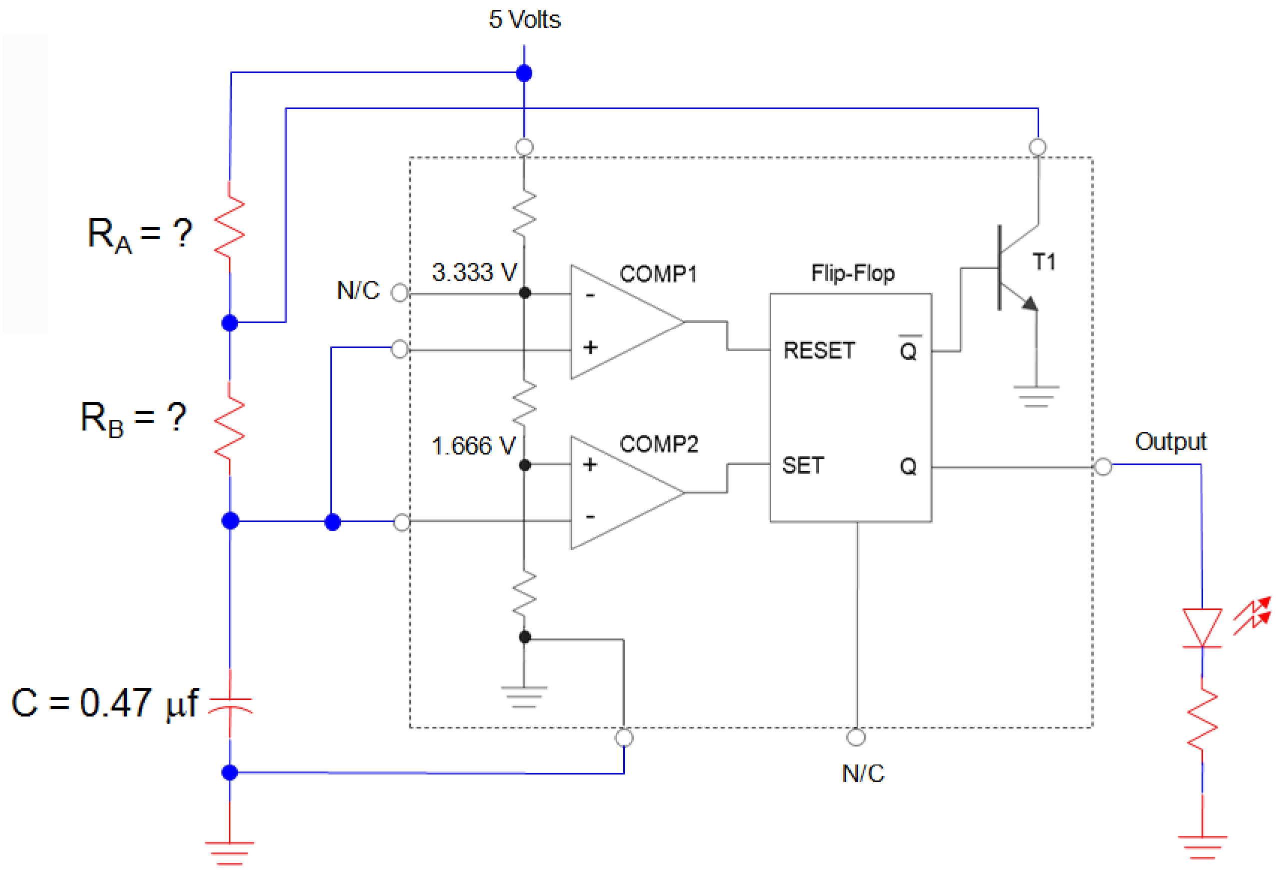
$$DC = \frac{\left(390\ \Omega + 180\ \Omega\right)}{\left(390\ \Omega + 2\times 180\ \Omega\right)}\times 100\%$$

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

Example: 555 Oscillator

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: 555 Oscillator

Solution:

<u>Frequency:</u>

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

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

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

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

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

<u>Duty Cycle:</u>

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

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

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

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

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

$$R_A = 0.5 \times R_B$$

Two Equations & Two Unknowns!

Example: 555 Oscillator

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

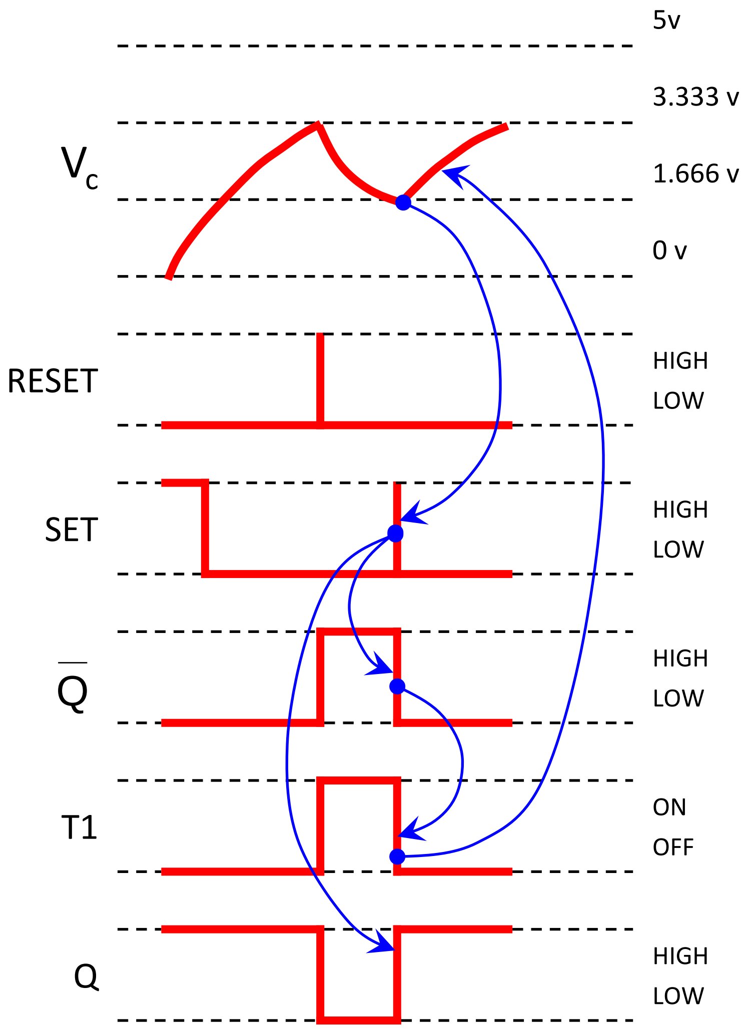
$$R_A + 2R_B = 1228.09\ \Omega$$

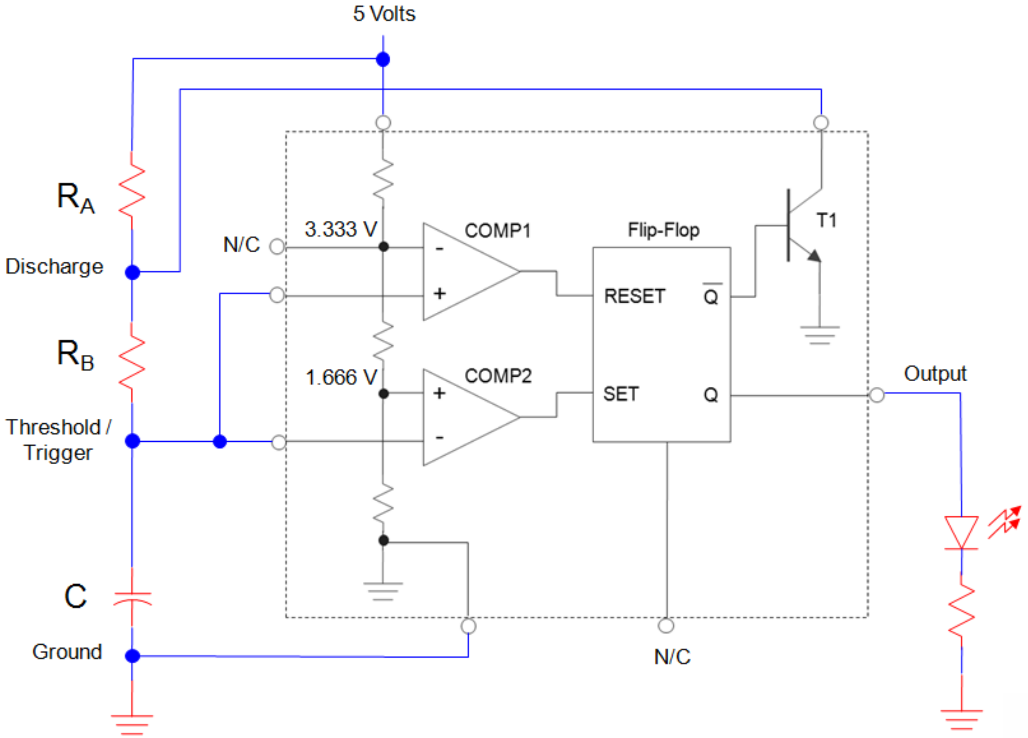
$$R_A + 2(491.23\ \Omega) = 1228.09\ \Omega$$

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

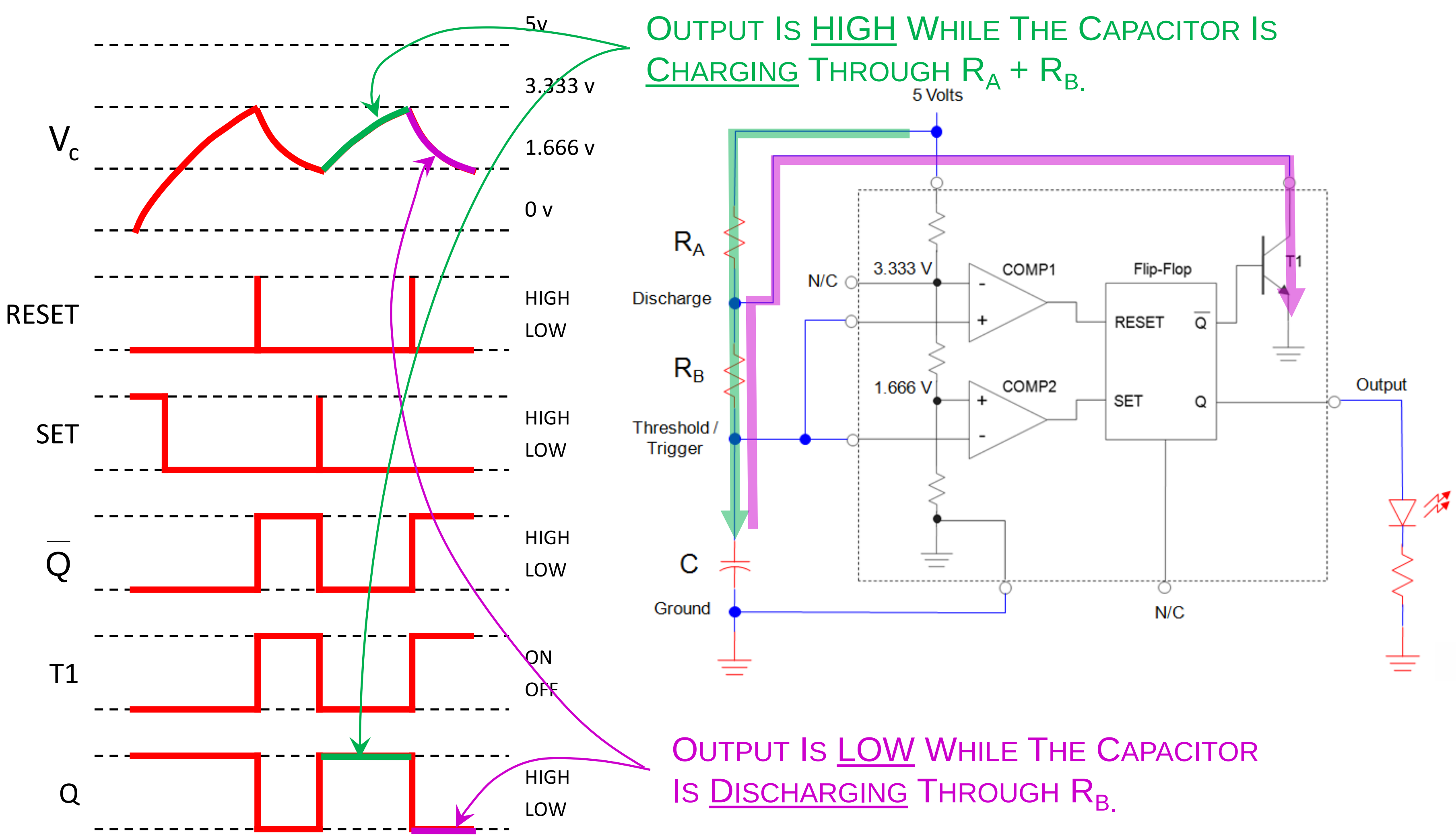
$$\boxed{R_A = 245.618\ \Omega}$$

Detail Analysis of a 555 Oscillator





Detail Analysis of a 555 Oscillator



555 Timer Design Equations

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

$$V_C = (V_{Final} - V_{Initial}) \times \left(1 - e^{-\frac{t}{RC}}\right) + V_{Initial}$$

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

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

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

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

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

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

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

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

$$t_{HIGH} = 0.693\,R\,C$$

$$t_{HIGH} = 0.693(R_A + R_B)C$$

555 Timer **Design** Equations

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

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

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

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

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

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

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

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

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

$$t_{LOW} = 0.693\,R$$

$$t_{LOW} = 0.693\,R_B C$$

555 Timer – Period / Frequency / DC

Period:

$$t_{HIGH} = 0.693\,(R_A + R_B)\,C$$

$$t_{LOW} = 0.693\,R_B C$$

$$T = t_{HIGH} + t_{LOW}$$

$$T = [0.693\,(R_A + R_B)\,C] + [0.693\,R_B C]$$

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

Duty Cycle:

$$DC = \frac{t_{HIGH}}{T} \times 100\%$$

$$DC = \frac{0.693\,(R_A + R_B)\,C}{0.693\,(R_A + 2R_B)\,C} \times 100\%$$

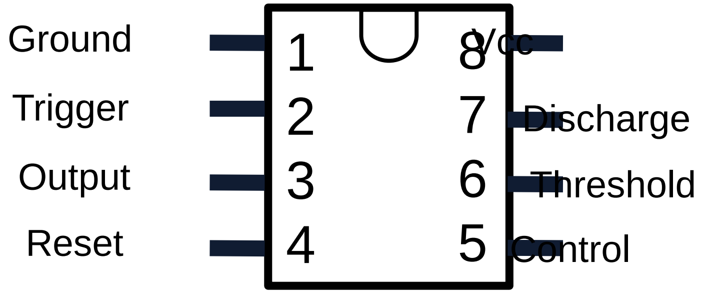
$$DC = \frac{(R_A + R_B)}{(R_A + 2R_B)} \times 100\%$$

Frequency:

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

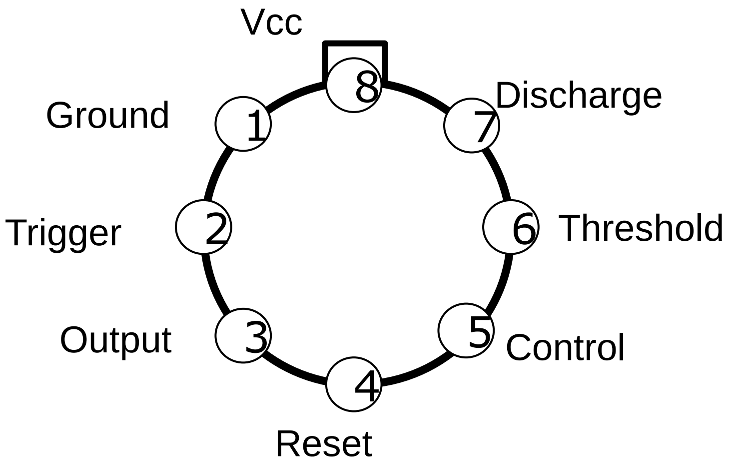
$$F = \frac{1}{0.693\,(R_A + 2R_B)\,C}$$

555 Layout

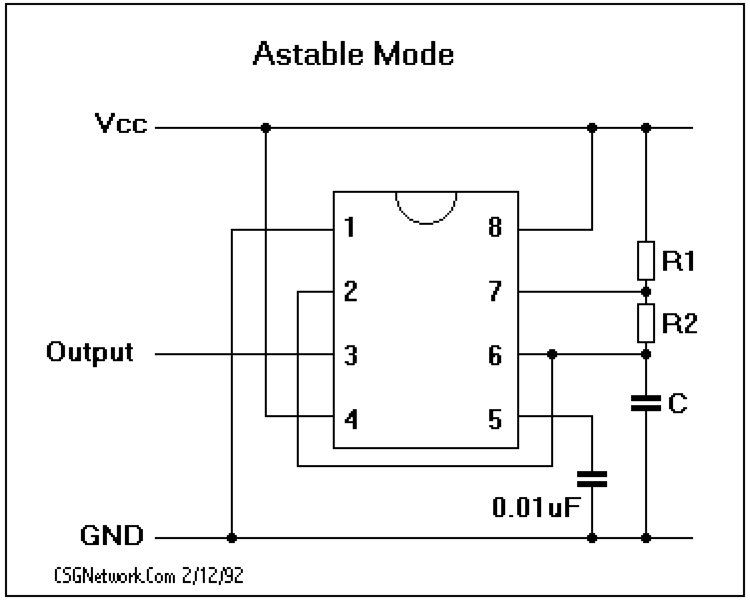


Also available:

- 556 (two-555's in one DIP package)
- 555 in a "metal can" configuration



Astable Multivibrator using 555



The positive output is high for T(h) seconds based on this formula:

T_H (sec)=0.693× (R1 + R2) ×C

The negative output is low for T(l) seconds based on this formula:

T_L (sec)=0.693× R2 ×C

The frequency is derived by the formula:

$$f = \frac{1.44}{(R1 + R2 + R3) \times C}$$

The duty cycle percentage is the relationship of the high time to the overall cycle time.