Timer 555

555 Timer

This presentation will

- Introduce the 555 Timer.
- Derive the characteristic equations for the charging and discharging of a capacitor.
- Present the equations for period, frequency, and duty cycle for a 555 Timer Oscillator.

Going Further….

- Detail the operation of a 555 Timer Oscillator.
- Derive the equations for period, frequency, and duty cycle for a 555 Timer Oscillator.

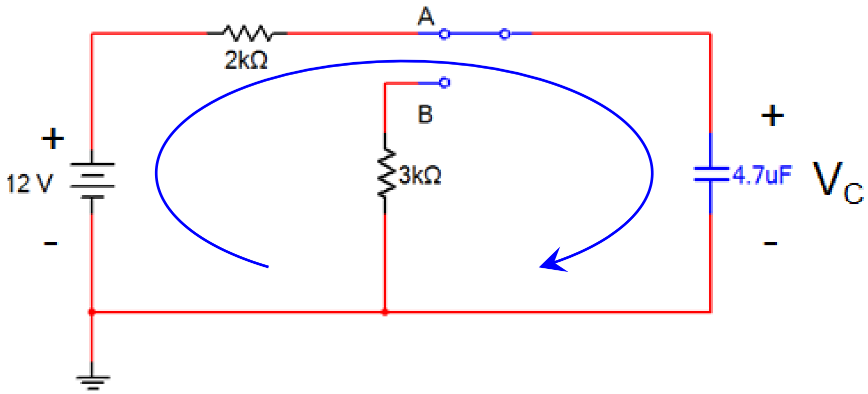
What is a 555 Timer?

- 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.
- This presentation will discuss how to use a 555 timer in the oscillator mode.

Capacitor

- A capacitor is an electrical component that can temporarily store a charge (voltage).
- The rate that the capacitor charges/discharges is a function of the capacitor's value and its resistance.
- To understand how the capacitor is used in the 555 Timer oscillator circuit, you must understand the basic charge and discharge cycles of the capacitor.

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>

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

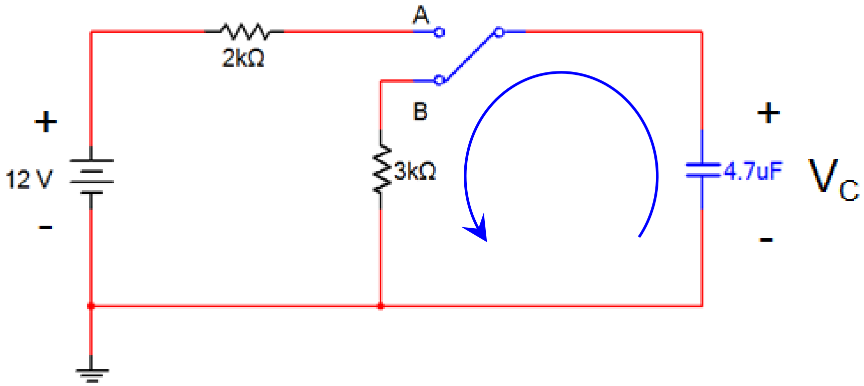
Where :

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

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

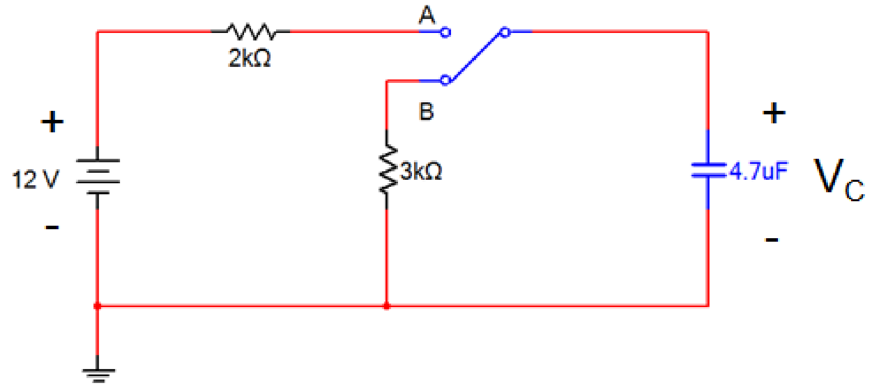
Where :

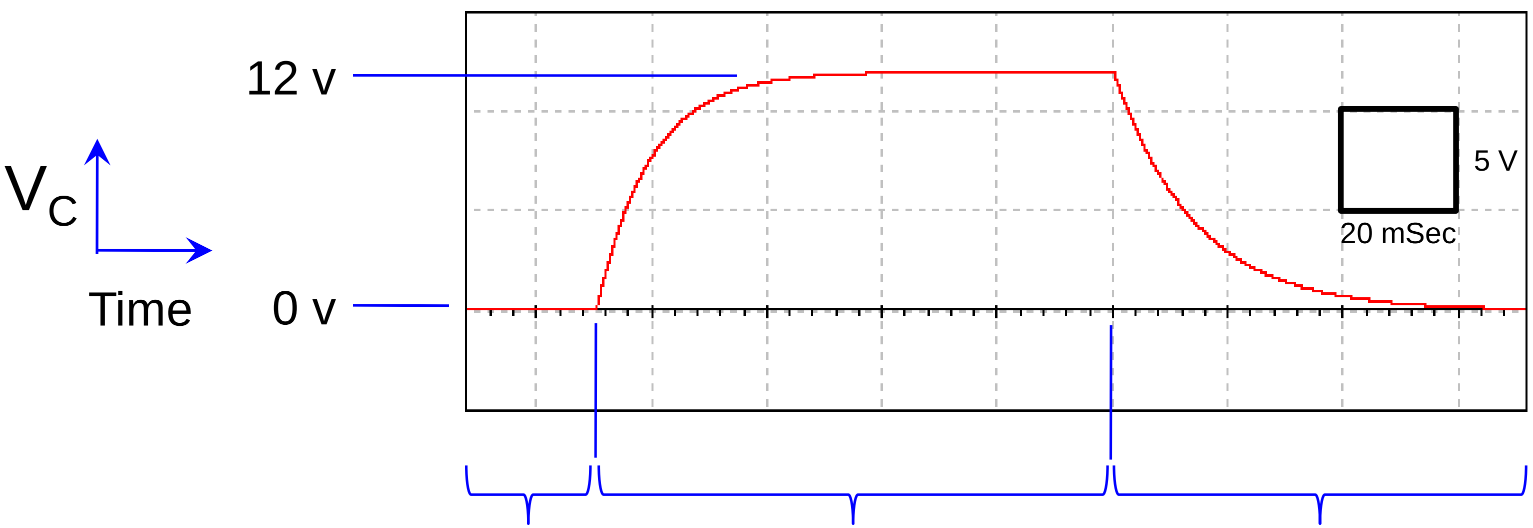
V_C = The voltage across the capacitor

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



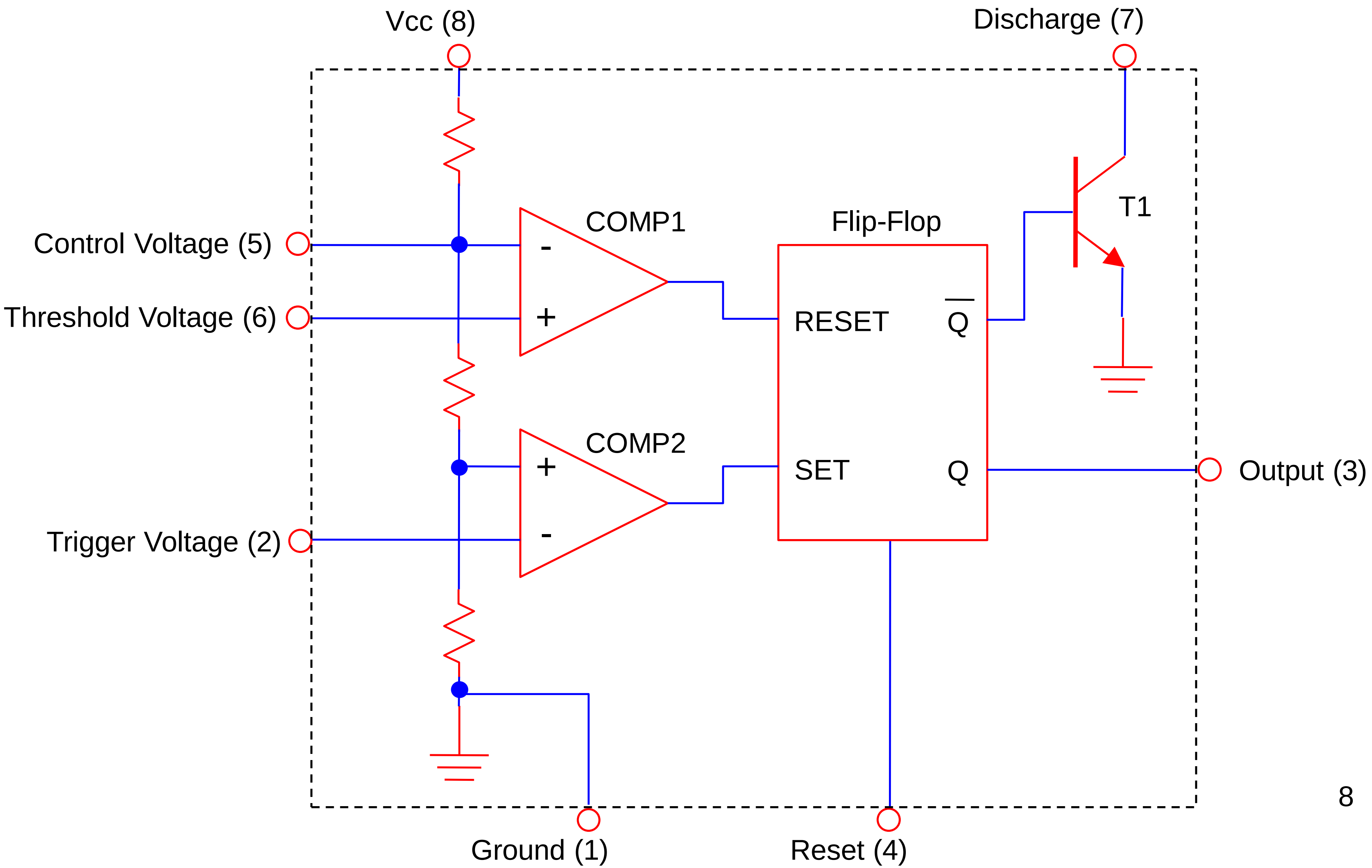


Switch has been at position B for a long period of time. The capacitor is completely discharged.

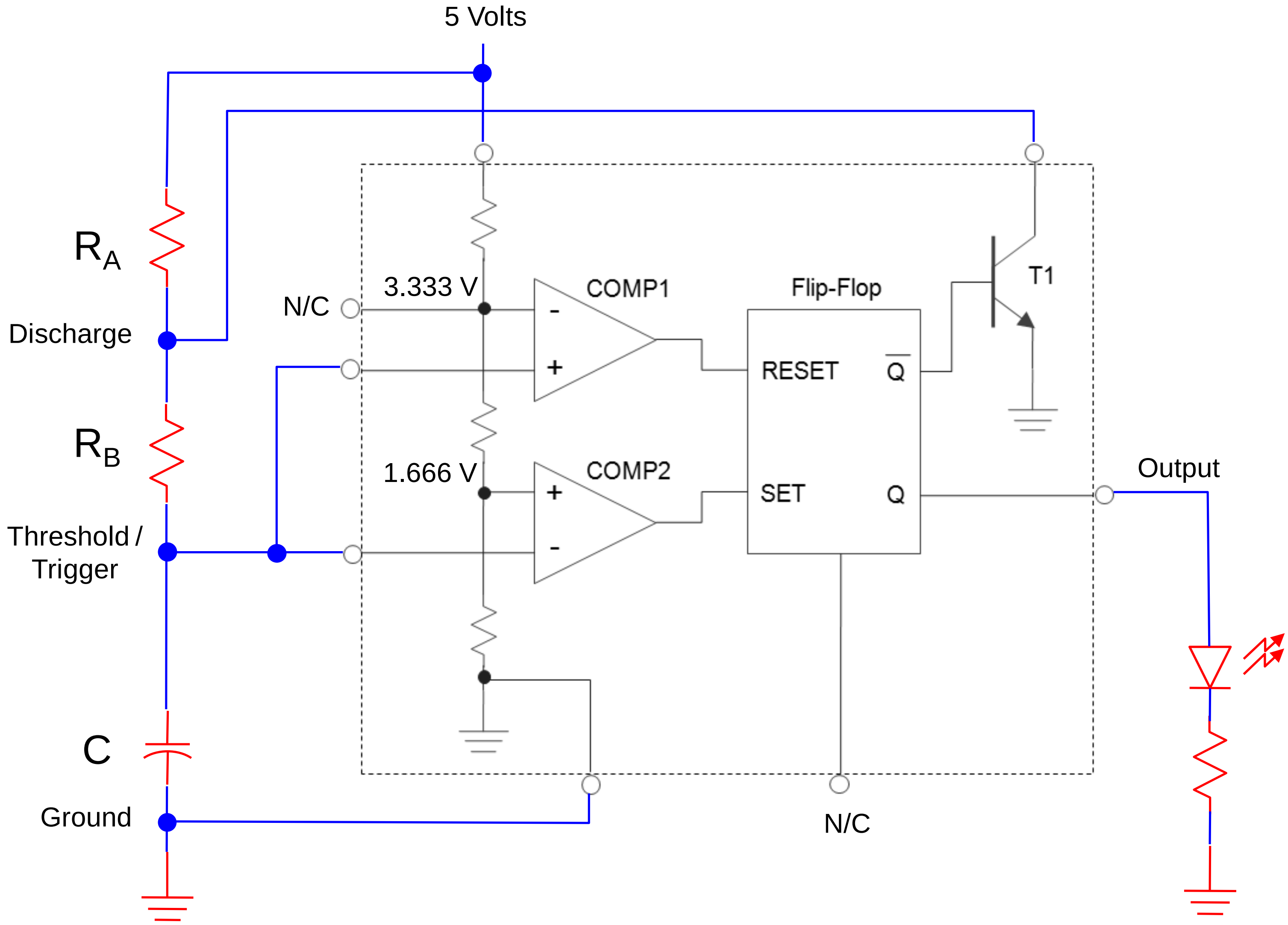
Switch is moved to position A. The capacitor charges through the 2KΩ resistor.

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

Block Diagram for a 555 Timer

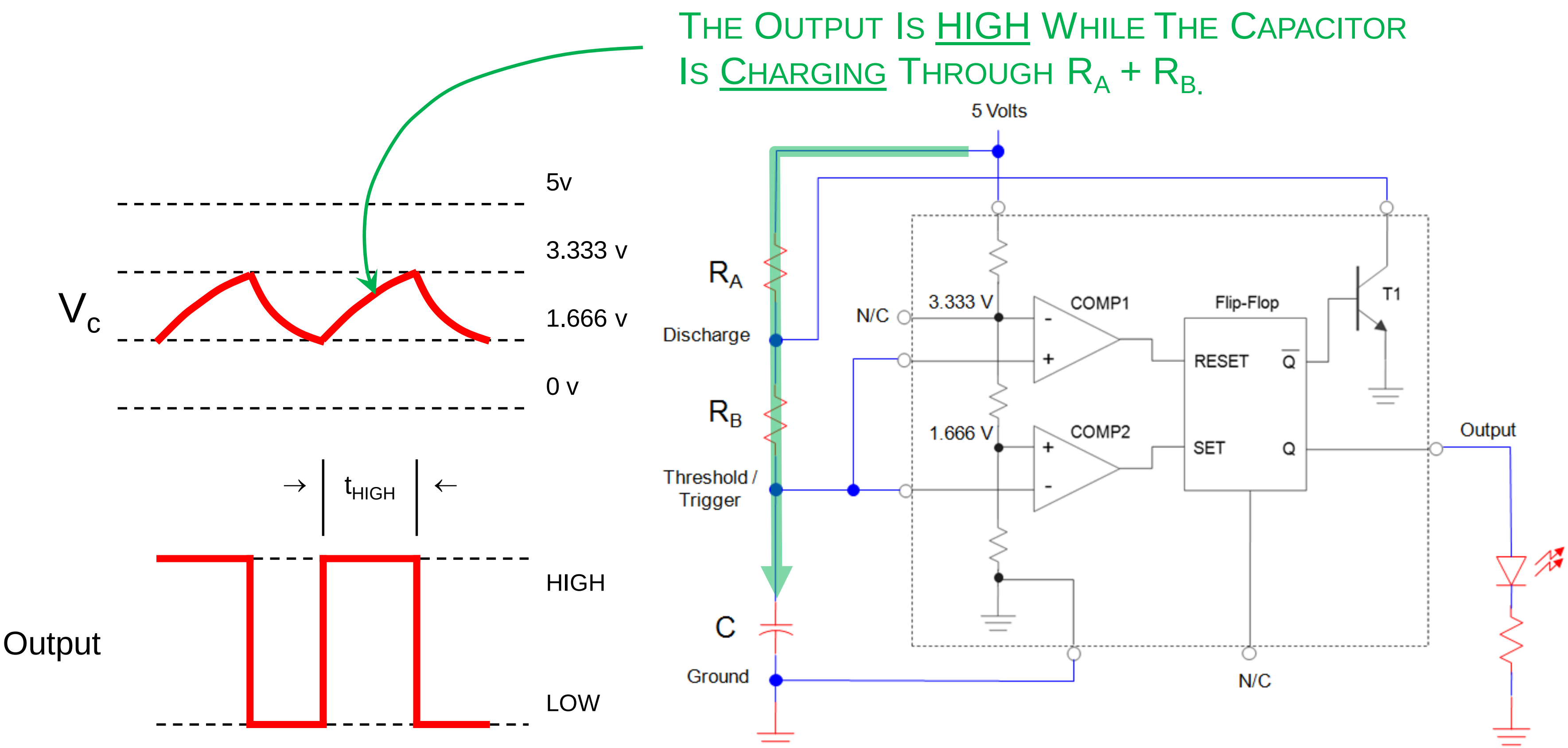


Schematic of a 555 Timer in Oscillator Mode



555 Timer Design Equations

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

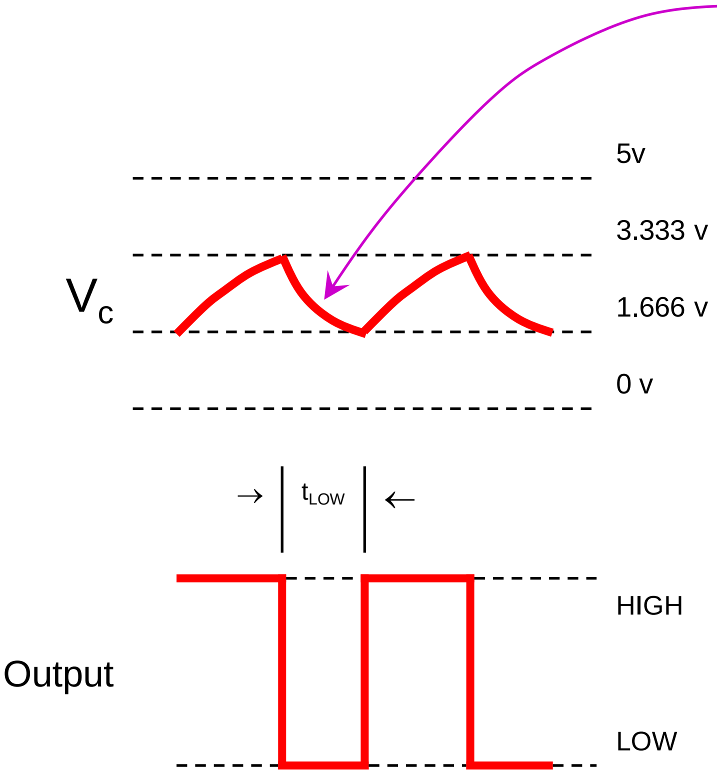


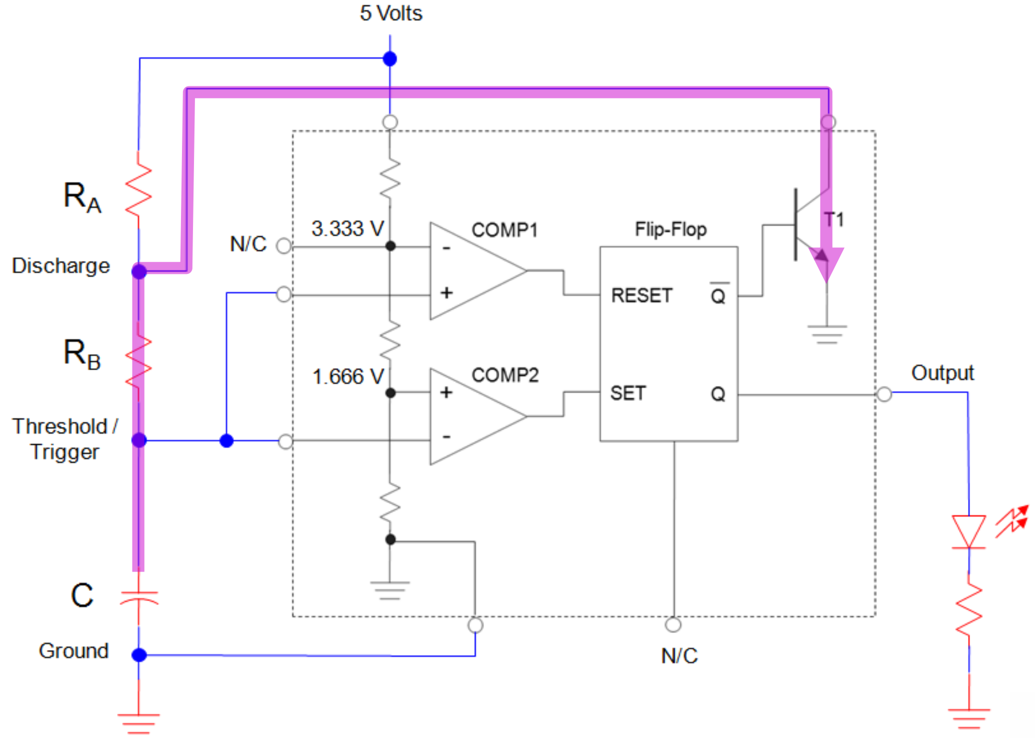
$$t_{HIGH} = 0.693(R_A + R_B)C$$

555 Timer Design Equations

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

THE OUTPUT IS LOW WHILE THE CAPACITOR IS DISCHARGING THROUGH R_B.





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

555 Timer – Period / Frequency / DC

Period:

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

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

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

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

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

Duty Cycle:

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

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

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

Frequency:

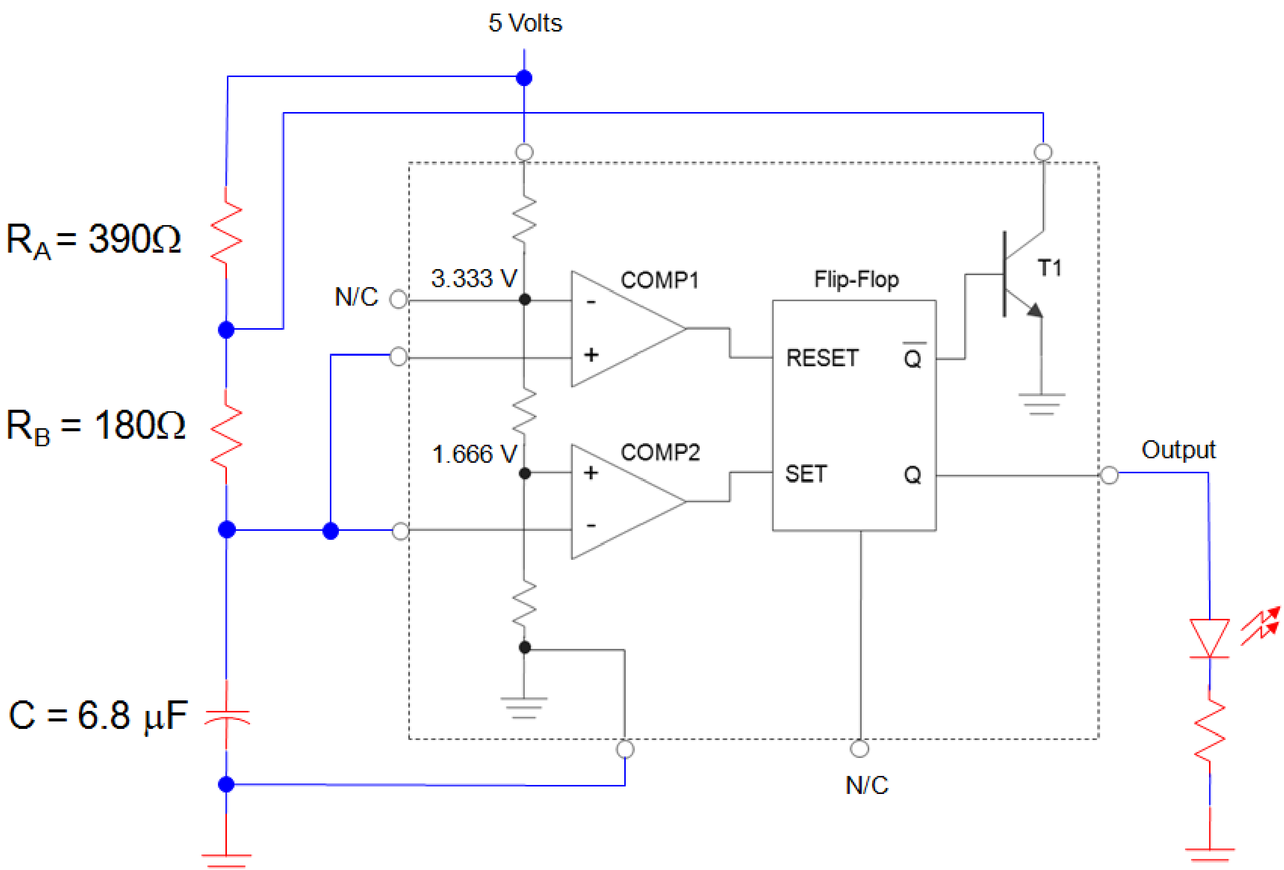
$$F = \frac{1}{T}$$

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

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:

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

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

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

Frequency:

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

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

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

Duty Cycle:

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

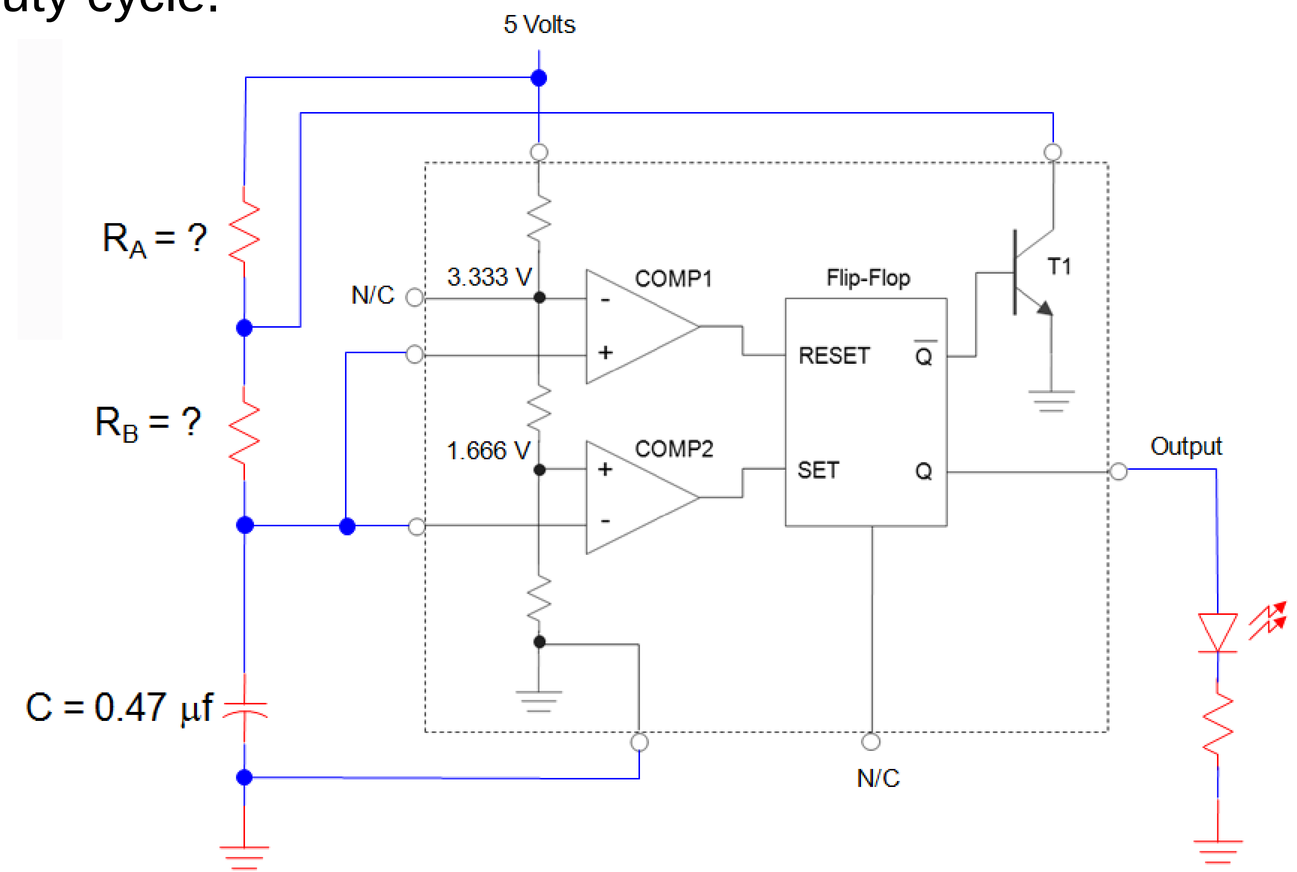
$$DC = \frac{(390\,\Omega + 180\,\Omega)}{(390\,\Omega + 2\times 180\,\Omega)}\times 100\%$$

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

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:

Frequency:

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

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

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

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

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

Duty Cycle:

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

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

$$R_A + R_B = 0.6\left(R_A + 2R_B\right)$$

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

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

$$R_A = 0.5 \times R_B$$

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 $R_{\mathbf{B}}$

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

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

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

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

Substitute and Solve for $R_{\mathbf{A}}$

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

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

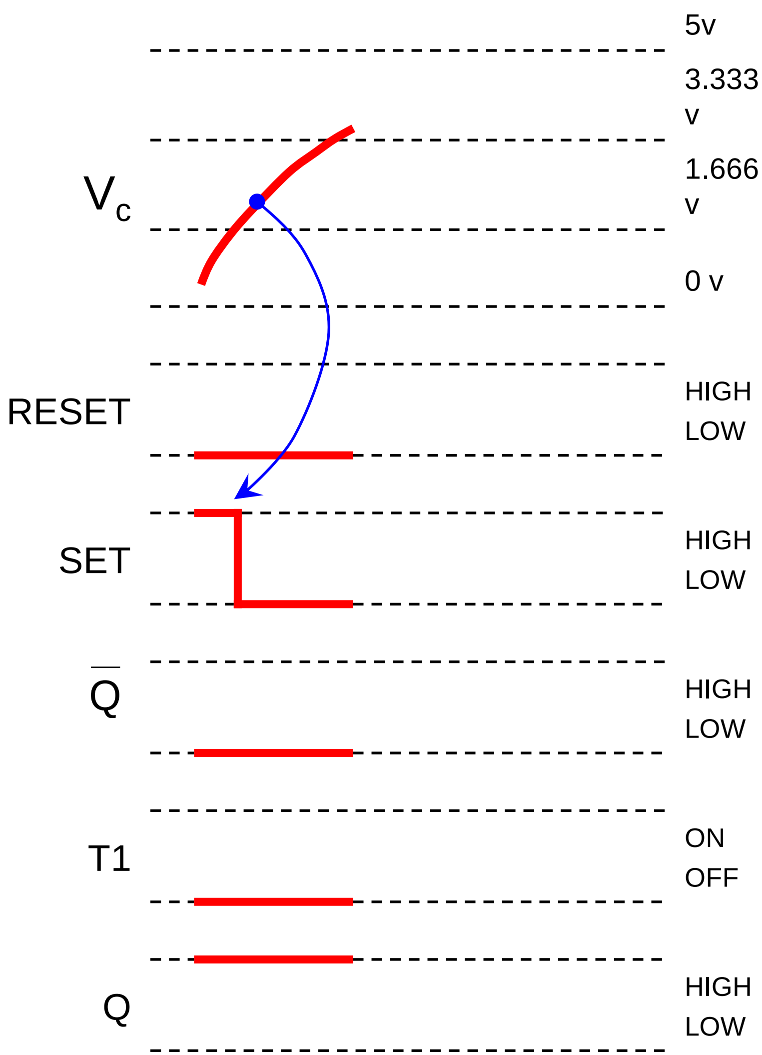
$$R_A + 982.472\,\Omega = 1228.09\,\Omega$$

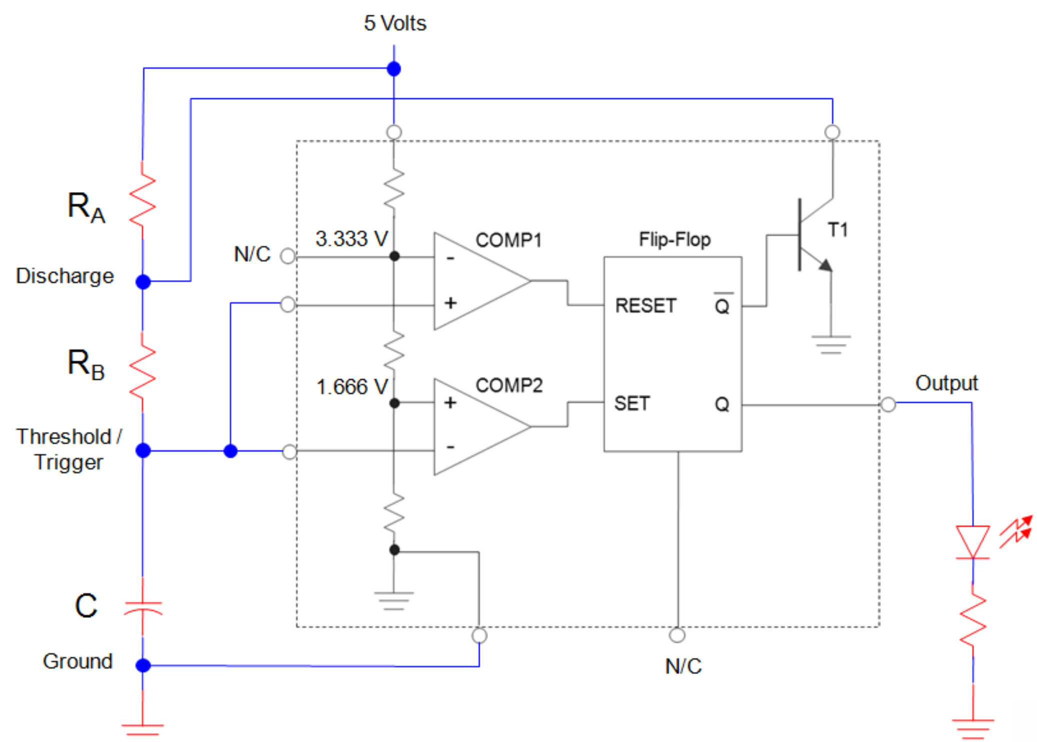
$$\boxed{R_A = 245.618\,\Omega}$$

Going Further…

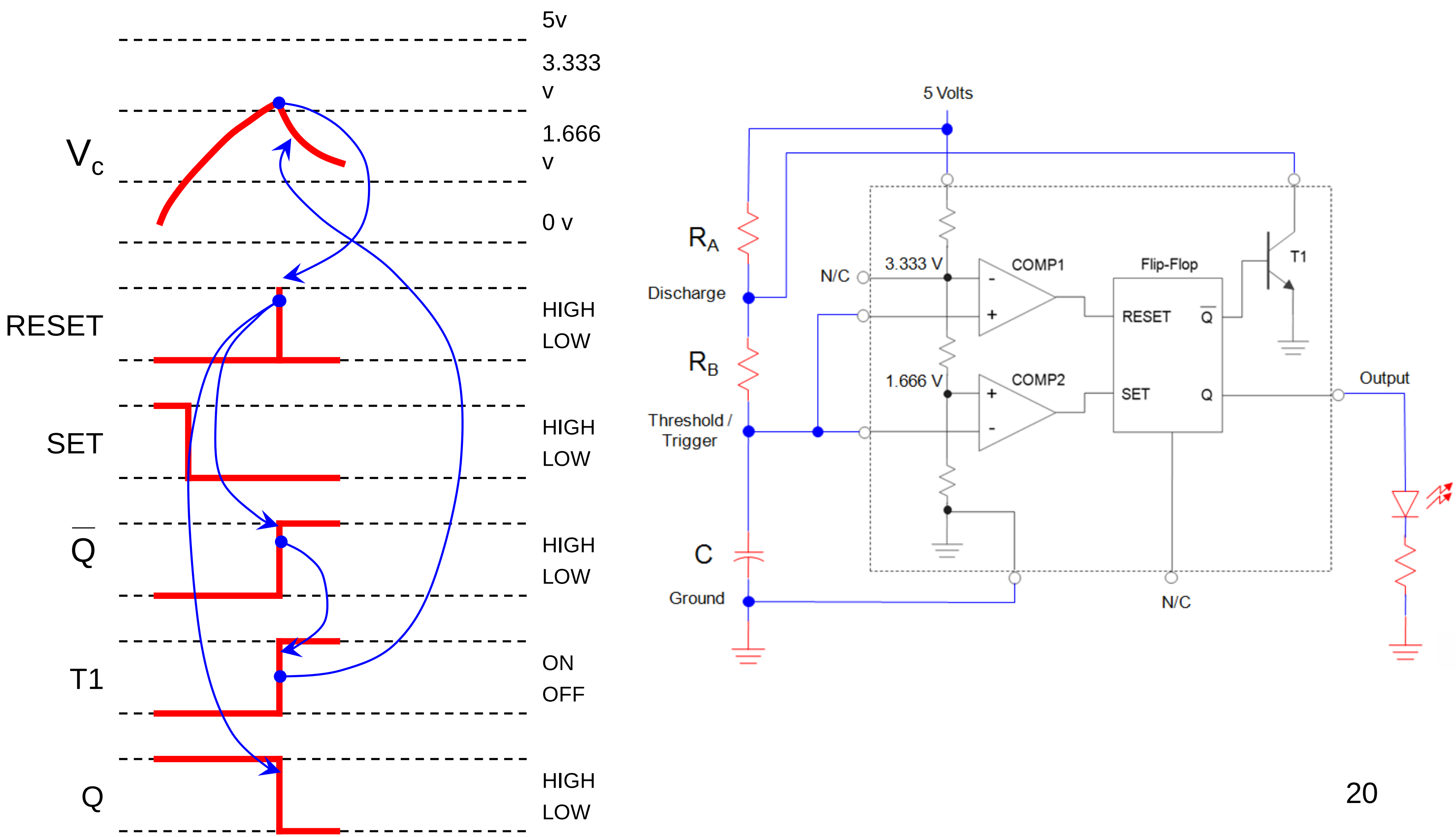
555 Oscillator
Detail Analysis

Detail Analysis of a 555 Oscillator

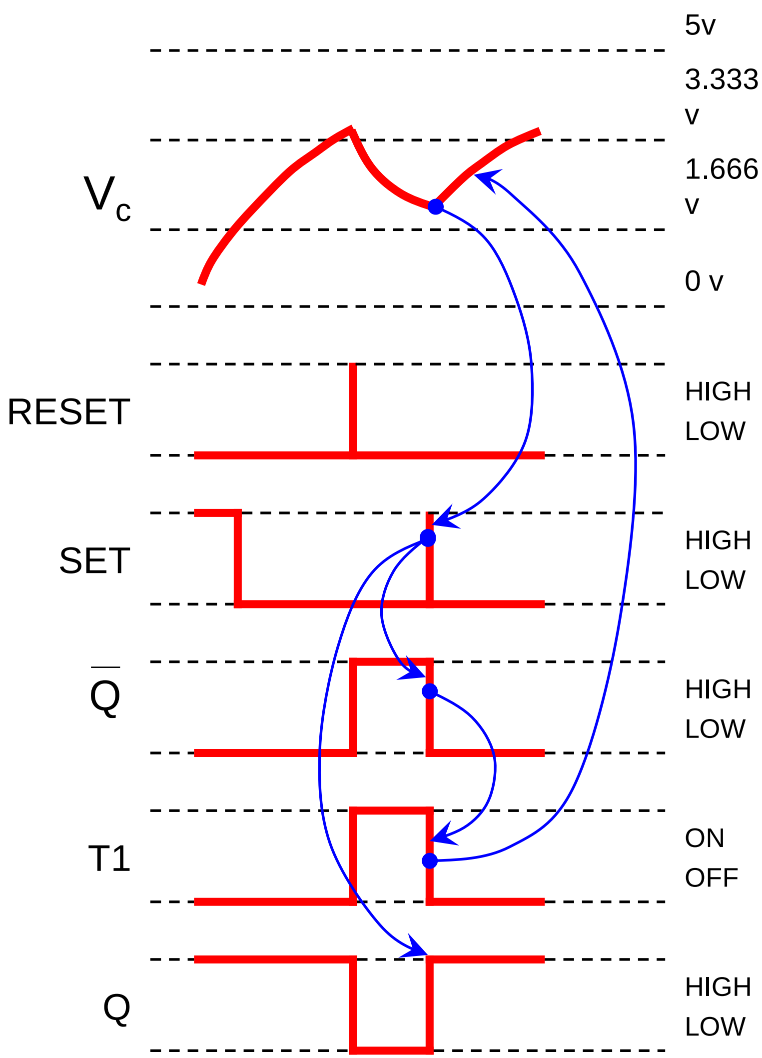


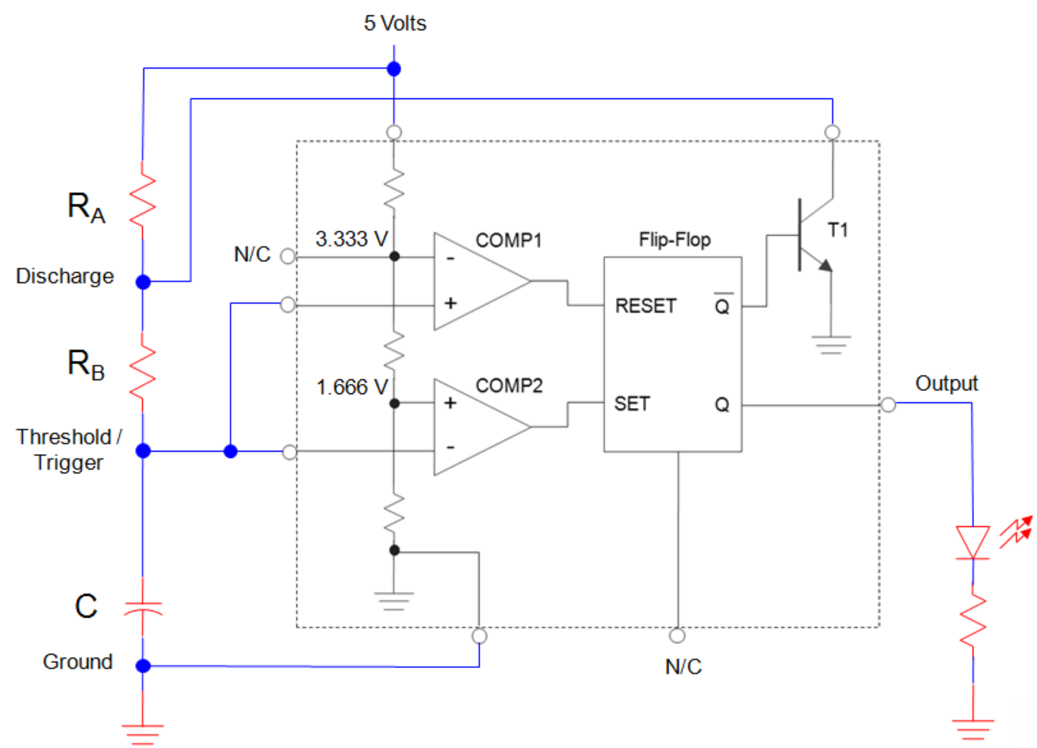


Detail Analysis of a 555 Oscillator

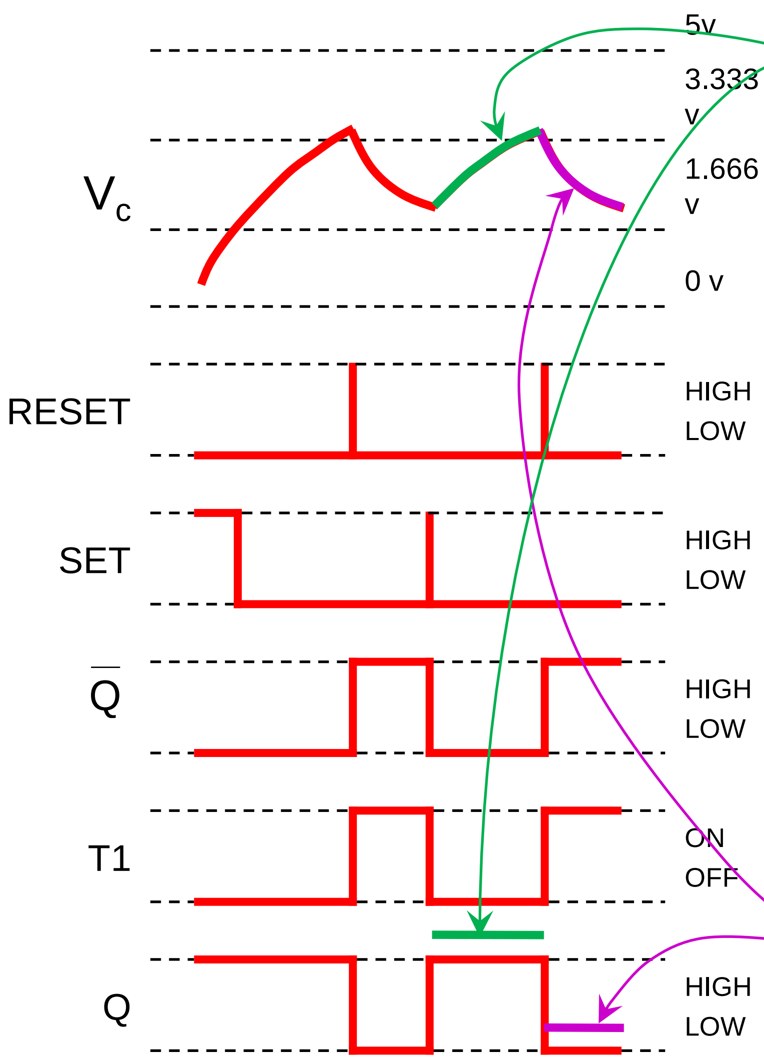


Detail Analysis of a 555 Oscillator

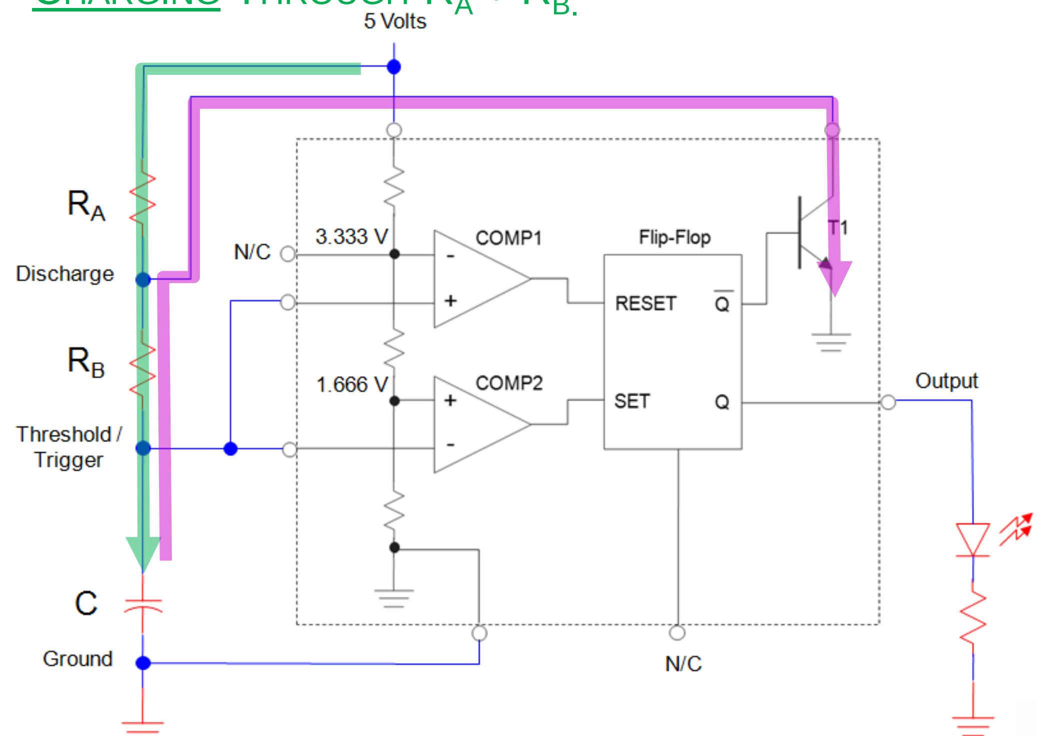




Detail Analysis of a 555 Oscillator



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



OUTPUT IS LOW WHILE THE CAPACITOR IS DISCHARGING THROUGH R_B.

555 Timer Design Equations

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

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

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

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

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

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

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

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

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

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

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

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

555 Timer Design Equations

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

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

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

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

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

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

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

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

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

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

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

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:

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

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

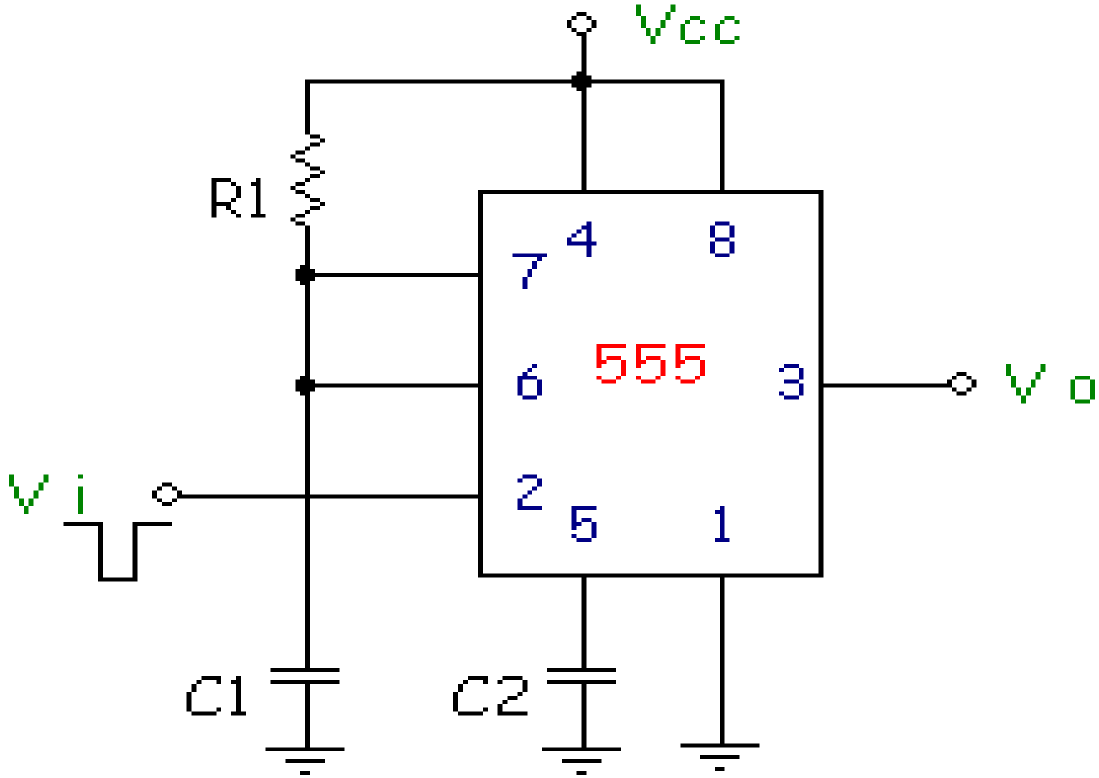
$$DC = \frac{(R_A + R_B)}{(R_A + 2R_B)} \times 100\%$$

Frequency:

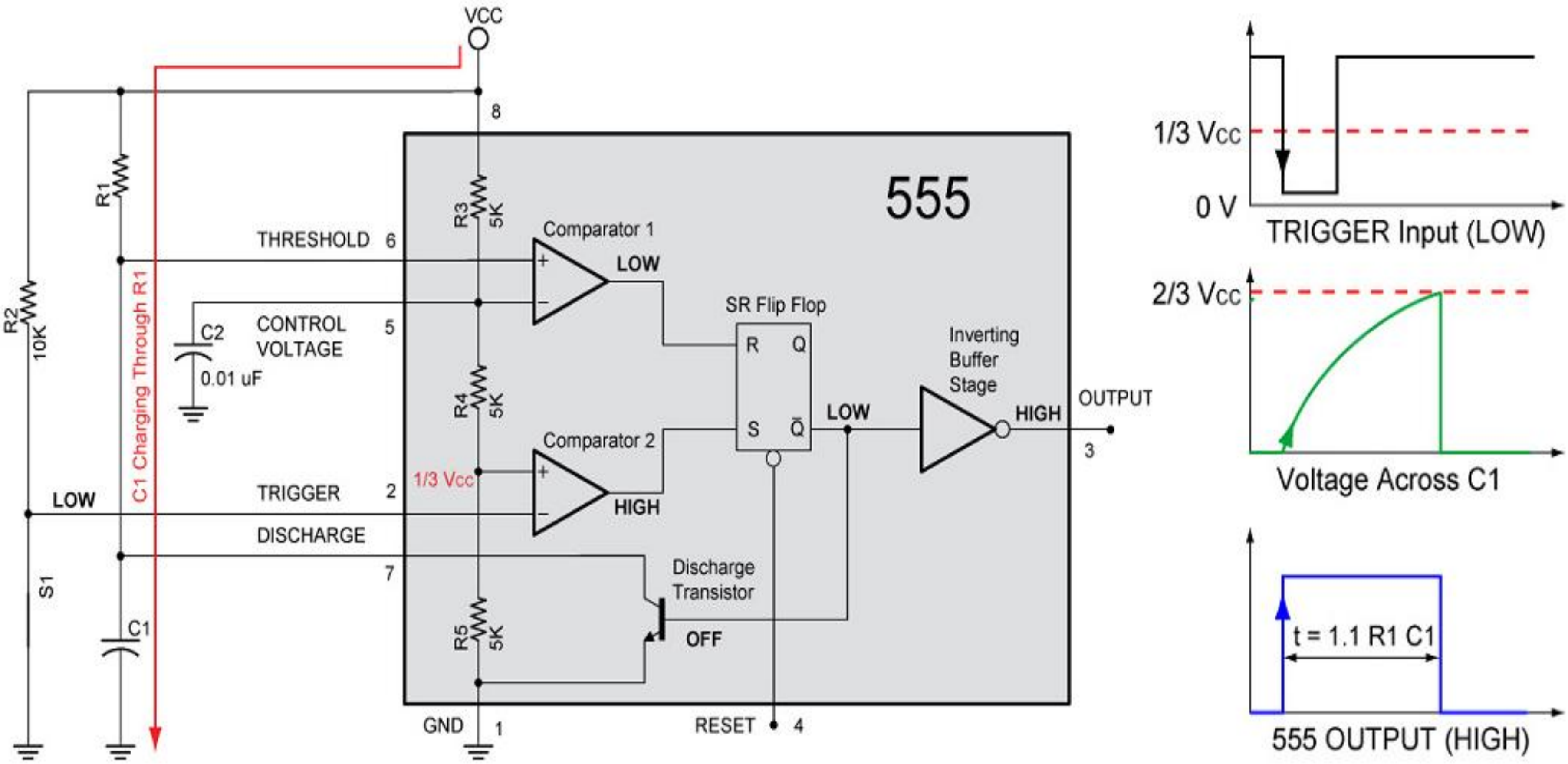
$$F = \frac{1}{T}$$

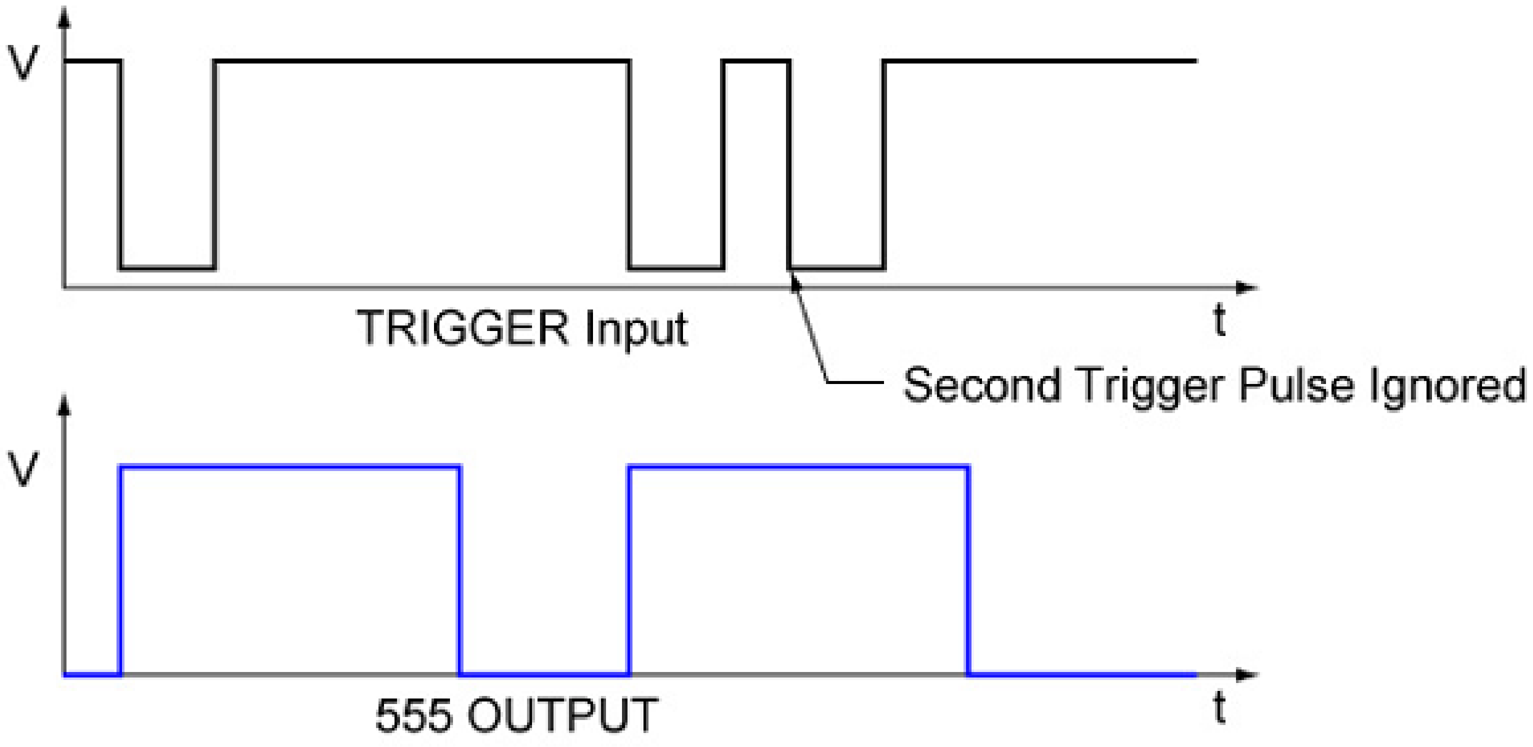
$$F = \frac{1}{0.693\,(R_A + 2R_B)\,C}$$

One shoot / mono stable oscillator



One shoot / mono stable oscillator




V
TRIGGER Input
t
Second Trigger Pulse Ignored
V
555 OUTPUT
t

555 Monostable Time Duration (Delay) Graph