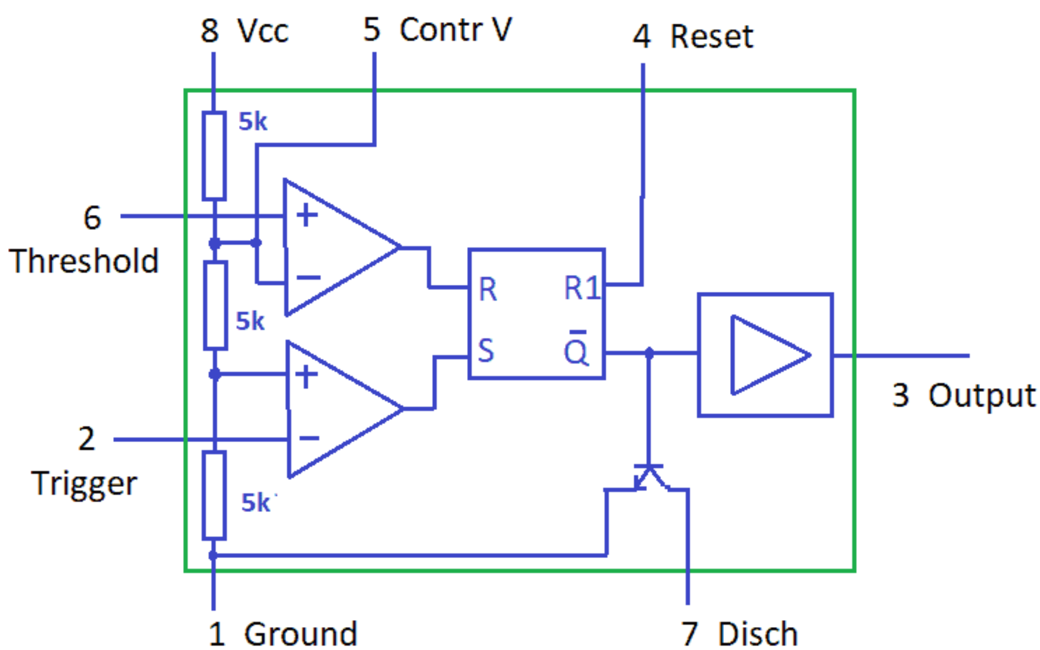
# LED Flasher

# The NE555 Timer IC




This is the internal circuit diagram of the NE555 Timer IC. We discuss components of the IC separately.

## Trigger and Threshold Pins

Note that the two comparators have one pin each connected to the voltage divider between $V_{cc}$ and Ground. So, the voltage at threshold pin is compared with $\frac{2V_{cc}}{3}$ and the voltage at trigger pin is compared with $\frac{V_{cc}}{3}$.

Hence,

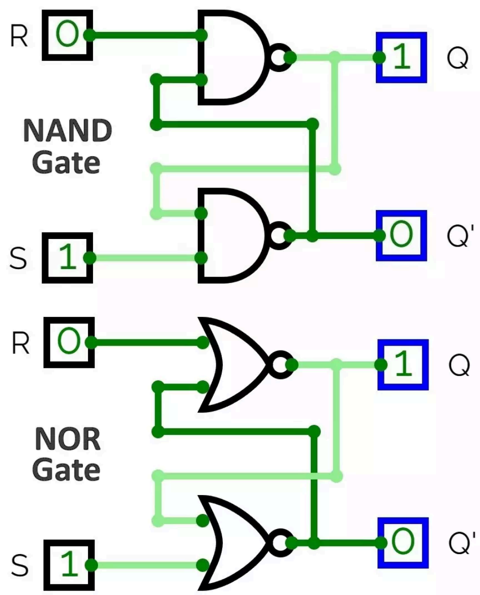
$$S = \left(Trigger < \frac{V_{cc}}{3}\right)?$$

$$R = \left(Threshold > \frac{2V_{cc}}{3}\right)?$$

Where the questions are answered in binary.

# The S-R latch/flip-flop

The box with $S, R, R_1, \bar{Q}$ follows the below truth table:




**SR Latch Truth Table**

| S | R | Q | Q' | State |
|---|---|---|---|---|
| 0 | 0 | Q | Q' | Hold (No Change) |
| 0 | 1 | 0 | 1 | Reset |
| 1 | 0 | 1 | 0 | Set |
| 1 | 1 | 0 | 0 | Invalid (Avoided) |

Note that if the R1 pin of the latch is grounded, the flip-flop turns off and gives an output of 0 always (it turns off the latch). So, in our schematic, we have kept R1 or the RESET pin always high.

The output of the S-R latch is connected through a NOT gate to the output. So, it essentially outputs $Q$.

# Control Voltage Pin

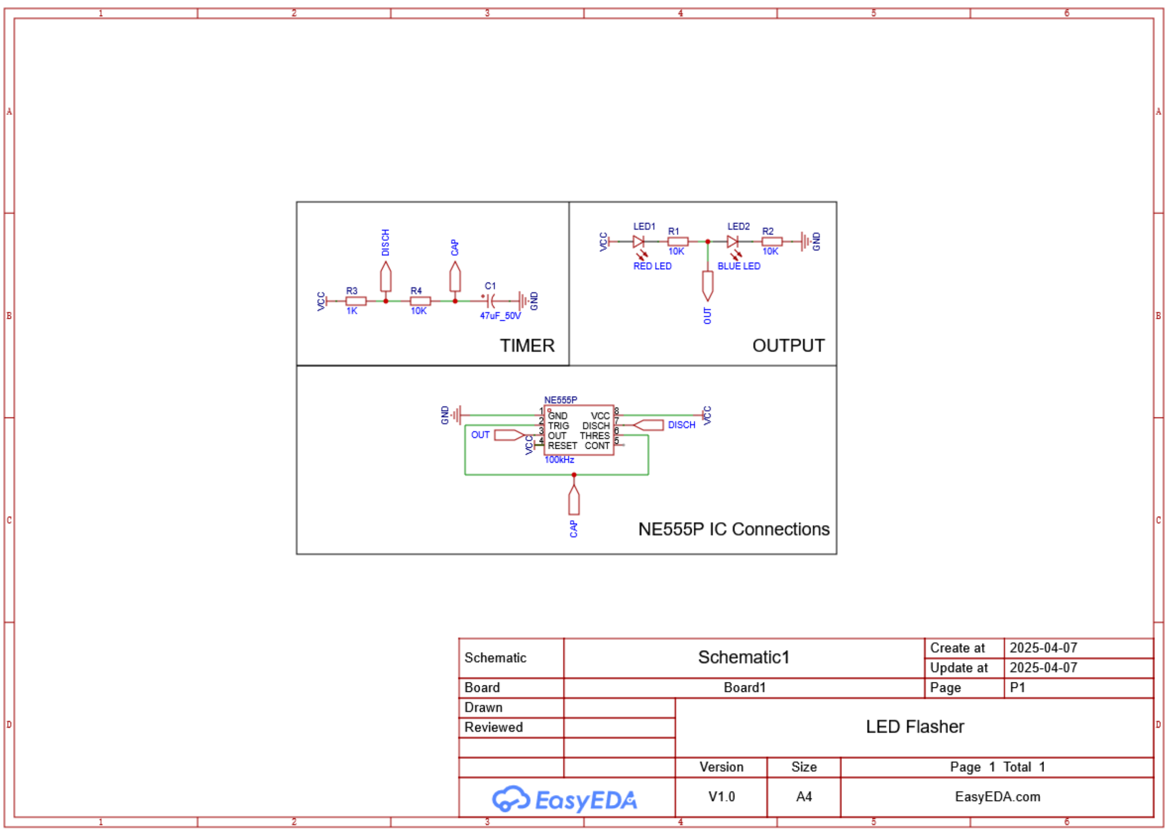
This pin basically gives a constant value of $\frac{2V_{cc}}{3}$. Changing the potential of this pin will change the values of the voltage divider voltages (being fed into the

comparators, does NOT affect Trigger and Threshold pins).
It is essentially useless for our purpose so we have left it hanging.

## Discharge Pin

This pin is connected to a transistor with $\bar{Q}$ as its gate/base. The transistor acts as a switch, when $\bar{Q}$ is high, the discharge pin is grounded.

# The Schematic




# OUTPUT Analysis

Note that when OUT ($Q$) is HIGH, the blue LED (connected between OUT and GND) will glow, and when OUT ($Q$) is LOW, the red LED (connected between VCC and OUT) will glow.
The 10k$\Omega$ resistors are just so that the current due to forward bias voltage of LED creates negligible current.

# A Note on IC Connections

Note that the TRIG and THRES pins are shorted. This is so that there is no condition where both of the outputs of the comparators are high.
Let $V_{TRIG} = V_{THRES} = V_C$ (Voltage across capacitor C1). As $V_C$ increases, we note that

$$S, R = \begin{cases} 1, 0 \text{ when } V_C \leq \frac{V_{cc}}{3} \\ 0, 0 \text{ when } \frac{V_{cc}}{3} < V_C < \frac{2V_{cc}}{3} \\ 0, 1 \text{ when } V_C \geq \frac{2V_{cc}}{3} \end{cases}$$

So, as $V_C$ increases from zero, there is no state where both S and R are 1 (invalid state for the SR Latch).

# TIMER Analysis

Assume the capacitor is discharged initially. So, the capacitor starts charging up, and the voltage across capacitor is

$$V_C = V_{cc} \left(1 - \exp\left(-\frac{t}{(R_3 + R_4)C}\right)\right)$$

Till $V_C \leq \frac{V_{cc}}{3}$, the output of the SR latch is 1 (Blue LED glows). After that, when $\frac{V_{cc}}{3} < V_C < \frac{2V_{cc}}{3}$, the SR latch is in latch position, meaning it remembers the previous information, and the output remains the same. Now, note that until now, $\bar{Q}$ is 0, meaning the discharge pin is not grounded. But as soon as $V_C \geq \frac{2V_{cc}}{3}$, the SR latch resets, making $Q = 0$ and $\bar{Q} = 1$ (Red LED glows), grounding the discharge pin.

Note that the time taken for the discharge pin to ground is

$$t_1 = (R_3 + R_4)C \ln(3)$$

Now, the discharge pin is grounded. This means the capacitor now discharges through the resistor $R_4$ with potential

$$V_C = \frac{2V_{cc}}{3} \exp\left(-\frac{t}{R_4 C}\right)$$

($t$ is measured after $t_1$)
Now, again, till $V_C > \frac{V_{cc}}{3}$, the SR Latch latches, remembering the previous state and the output remains the same.
The time of glowing of the red LED is

$$t_R = R_4 C \ln(2)$$

As soon as $V_C \leq \frac{V_{cc}}{3}$, the SR Latch sets, making $Q = 1$ and $\bar{Q} = 0$ (Blue LED glows), the discharge pin is ungrounded and the capacitor starts charging back again through resistors $R_3$ and $R_4$.

$$V_C = \frac{2V_{cc}}{3}\left(1 - \exp\left(-\frac{t}{(R_3 + R_4)C}\right)\right) + \frac{V_{cc}}{3}$$

And, the cycle continues. The blue LED glows until $V_C = \frac{2V_{cc}}{3}$, capacitor starts discharging, red LED glows, blablabla.
So the time of glowing of the blue LED is

$$t_B = (R_3 + R_4)C \ln(2)$$

Note that $t_B \neq t_R$, meaning the blue LED stays on for a little bit longer than the red LED. However, we cannot eliminate $R_3$ to fix that since when the discharge pin is grounded ($V_C > \frac{2V_{cc}}{3}$), a current $i = \frac{V_{cc}}{R_3}$ must flow from $V_{cc}$ to the discharge pin. This current should be low enough to not blow up the IC.

Also note that the capacitor charges for $t_1$ only at the start (when it is discharged initially), and then potential across it starts oscillating between $\frac{V_{cc}}{3}$ and $\frac{2V_{cc}}{3}$.

| R4 Resistance | C1 Capacitance | Red LED Glow Time | Blue LED Glow Time |
|---|---|---|---|
| 10kΩ | 47uF | 0.326s | 0.358s |
| 10kΩ | 100uF | 0.693s | 0.762s |
| 22kΩ | 47uF | 0.718s | 0.749s |
| 22kΩ | 100uF | 1.525s | 1.594s |