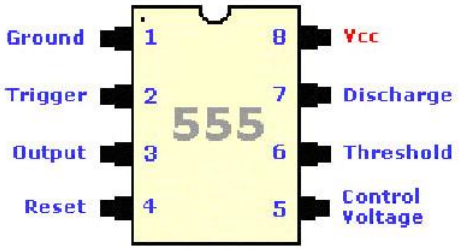
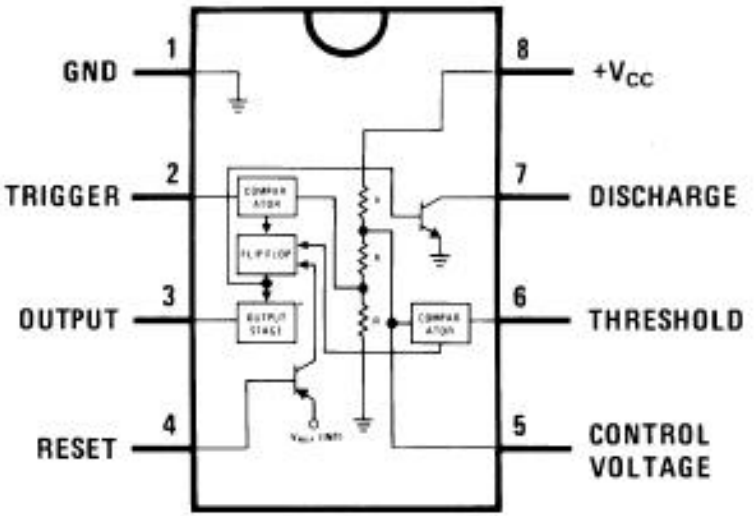
555 Timer

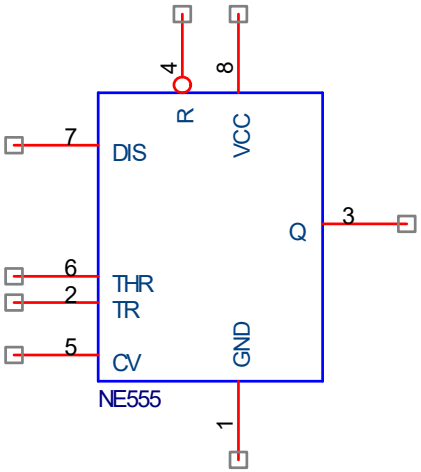


- The 555 Timer is one of the most popular and versatile integrated circuits ever produced!
- It is 30 years old and still being used!
- It is a combination of digital and analog circuits.
- It is known as the "time machine" as it performs a wide variety of timing tasks.
- Applications for the 555 Timer include:
  - Bounce-free switches and Cascaded timers
  - Frequency dividers
  - Voltage-controlled oscillators
  - Pulse generators and LED flashers

555 Timer

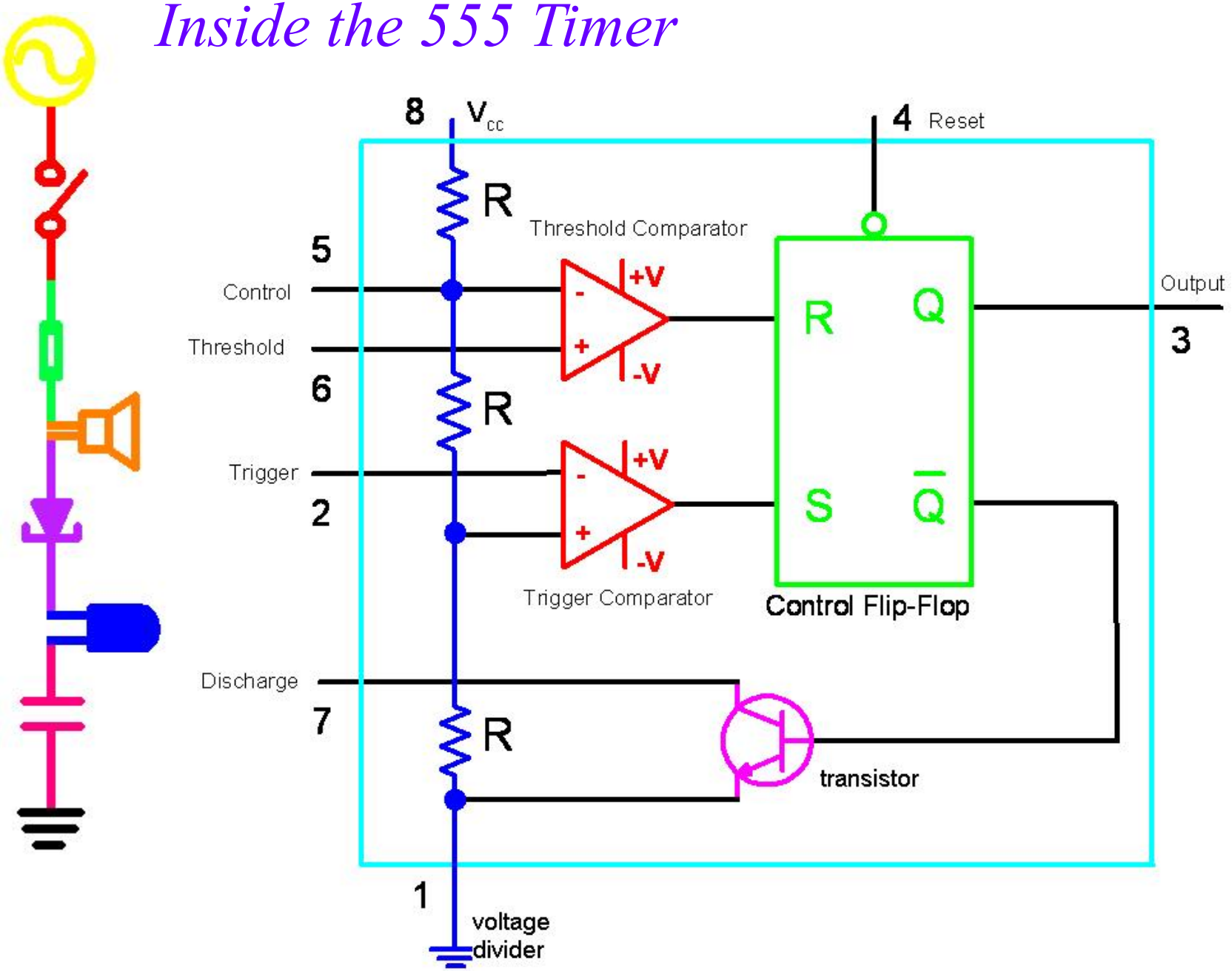


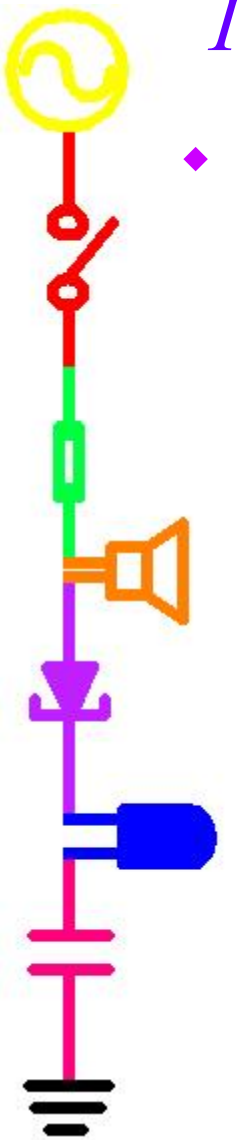
Top View



- Each pin has a function, the meaning of which will become clearer later.
- Note some familiar components inside

Inside the 555 Timer

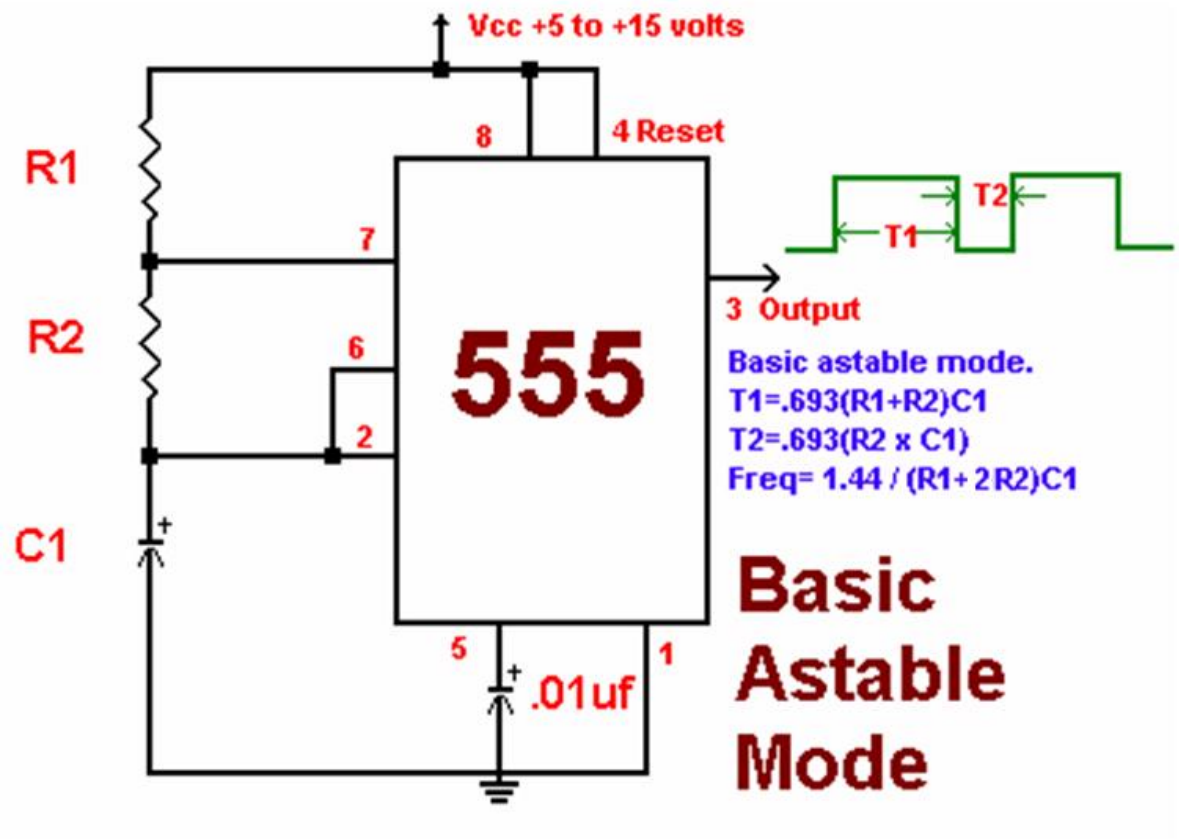




Inside the 555 Timer

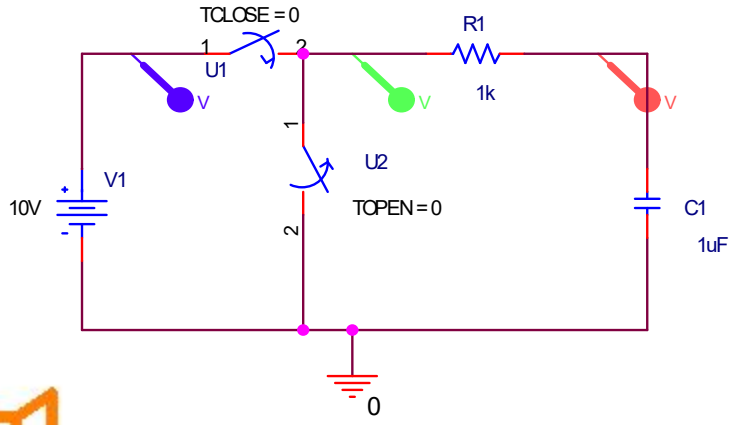
- You will learn more about these components later in the course, for now just understand the following:
  - The voltage divider has three equal 5K resistors. It divides the input voltage (Vcc) into three equal parts.
  - The two comparators are op-amps which compare the voltages at their inputs and saturate depending upon which is greater.
  - The flip-flop is a bi-stable device. It generates two values, a “high” value equal to Vcc and a “low” value equal to 0V.
  - The transistor is being used as a switch, it connects pin 7 (discharge) to ground when it is closed.

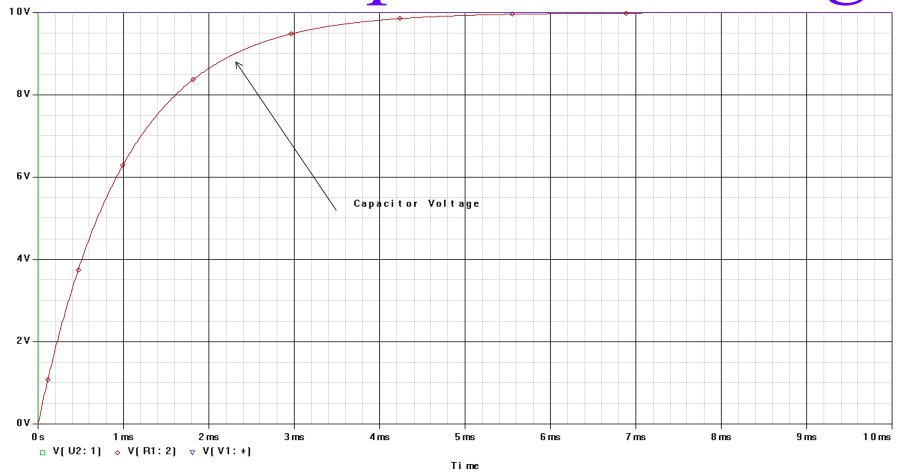
Periodic Pulse Train from a 555 Timer



- 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.

First we must examine how capacitors charge



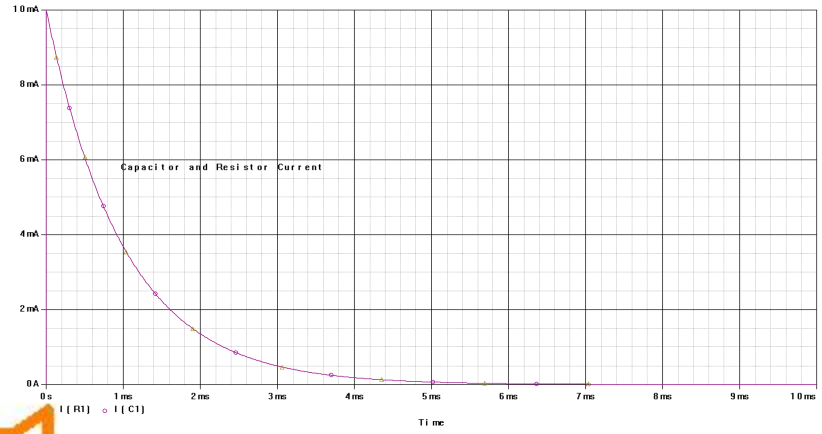


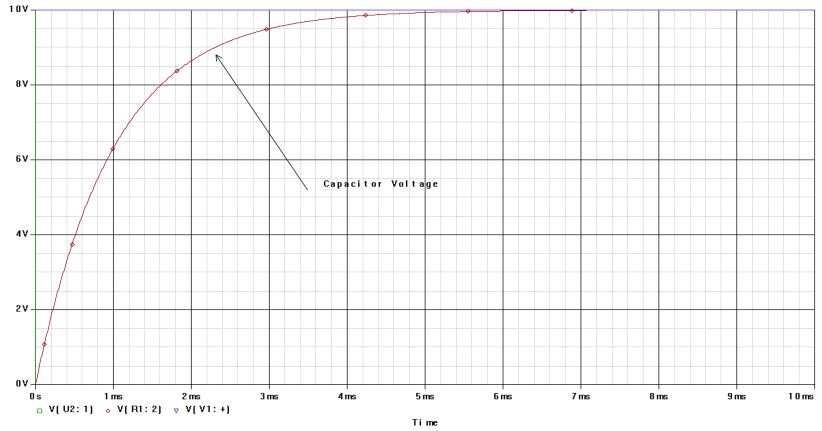
- Capacitor C1 is charged up by current flowing through R1

$$I = \frac{V1 - V_{CAPACITOR}}{R1} = \frac{10 - V_{CAPACITOR}}{1k}$$

- As the capacitor charges up, its voltage increases and the current charging it decreases, resulting in the charging rate shown

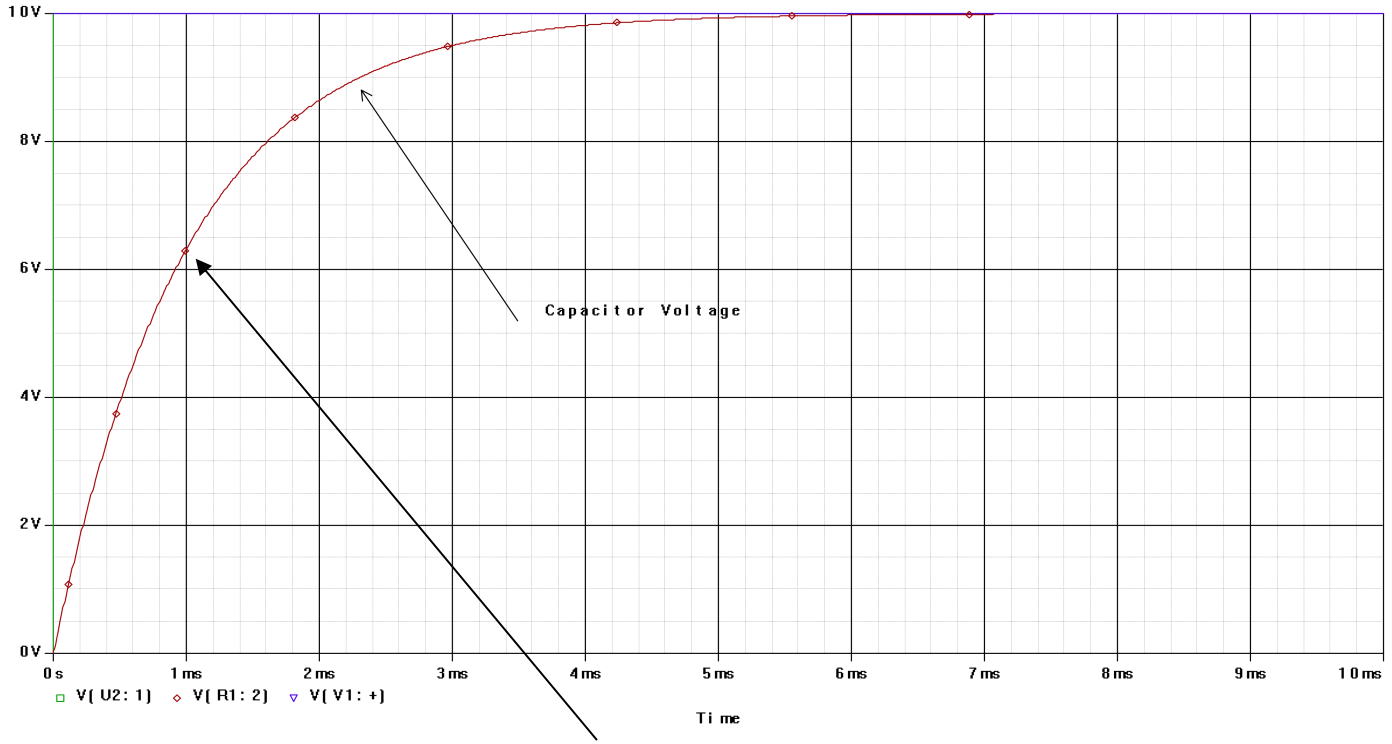
Capacitor Charging Equations





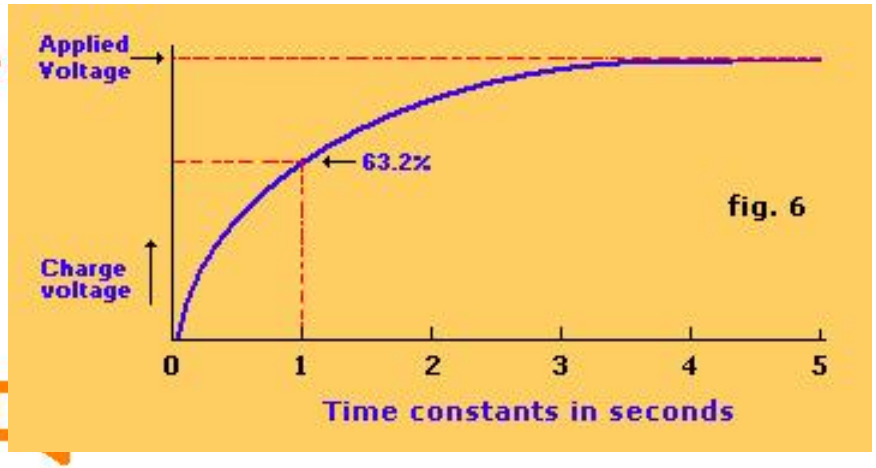
- Capacitor Current $I = I_o e^{-t/\tau}$
- Capacitor Voltage $V = V_o\left(1 - e^{-t/\tau}\right)$
- Where the time constant $\tau = RC = R1 \cdot C1 = 1ms$

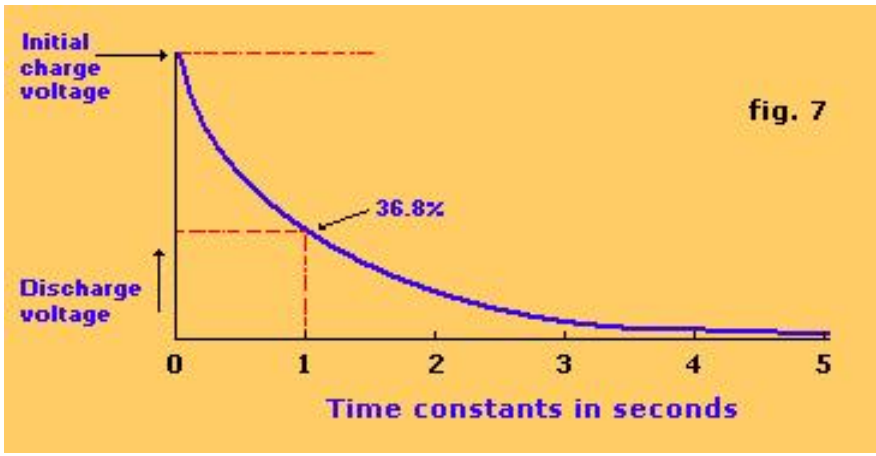
Understanding the equations



- Note that the voltage rises to a little above 6V in 1ms. $(1-e^{-1})=.632$

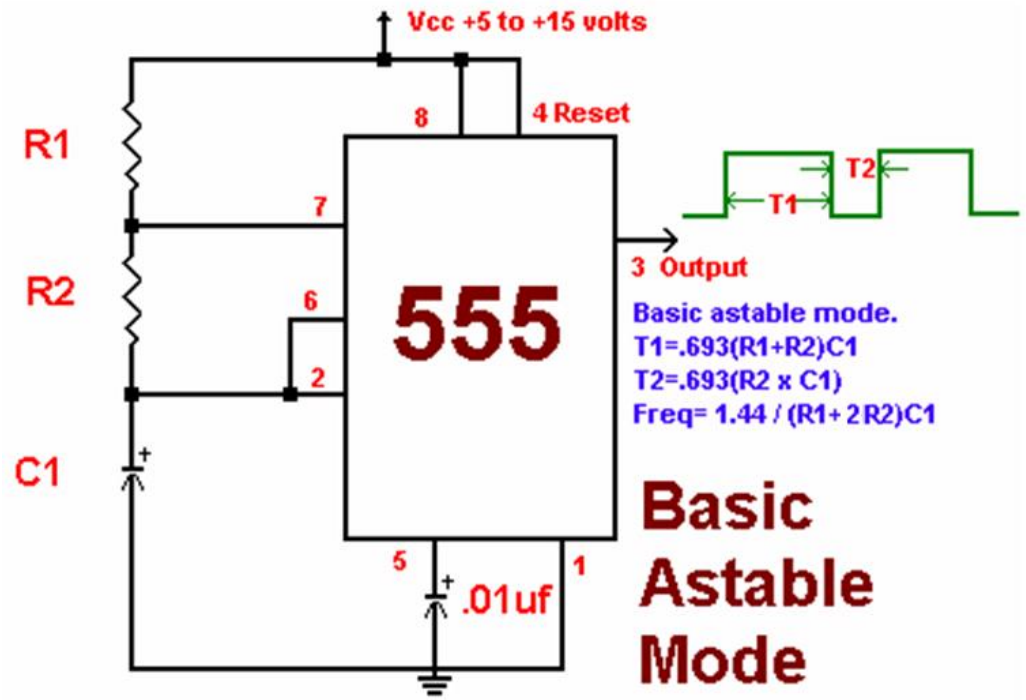
Capacitor Charging and Discharging





- There is a good description of capacitor charging and its use in 555 timer circuits at http://www.uoguelph.ca/~antoon/gadgets/555/555.html

555 Timer



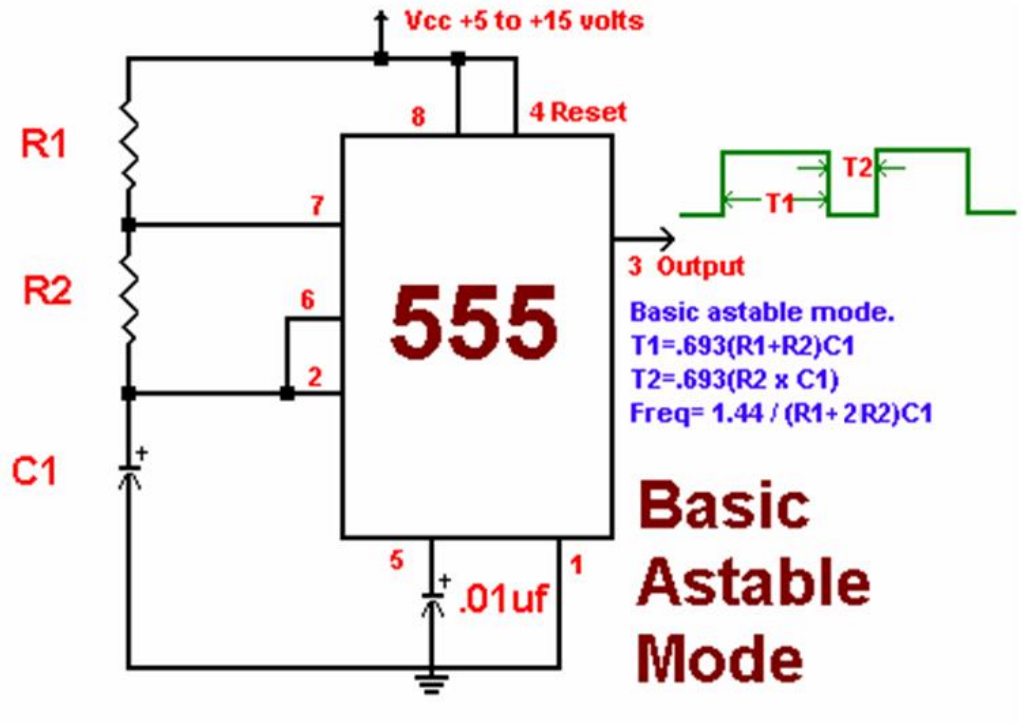
- At the beginning of the cycle, C1 is charged through resistors R1 and R2. The charging time constant is

$$\tau = (R1 + R2)C1$$

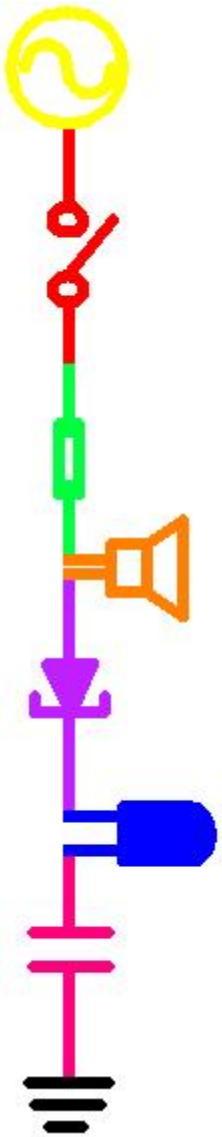
- The voltage reaches (2/3)Vcc in a time

$$\tau = 0.693(R1 + R2)C1$$

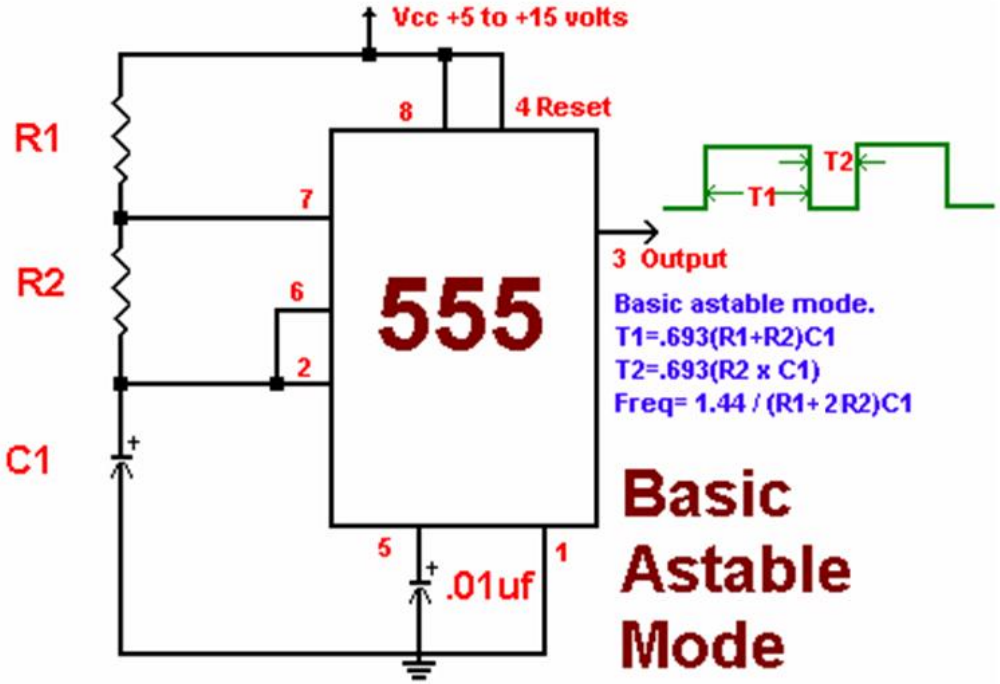
555 Timer



- When the voltage on the capacitor reaches (2/3)Vcc, a switch (the transistor) is closed at pin 7 and the capacitor is discharged to (1/3)Vcc, at which time the switch is opened and the cycle starts over

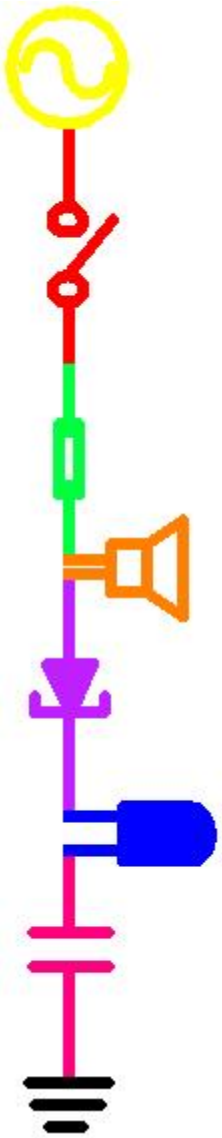


555 Timer

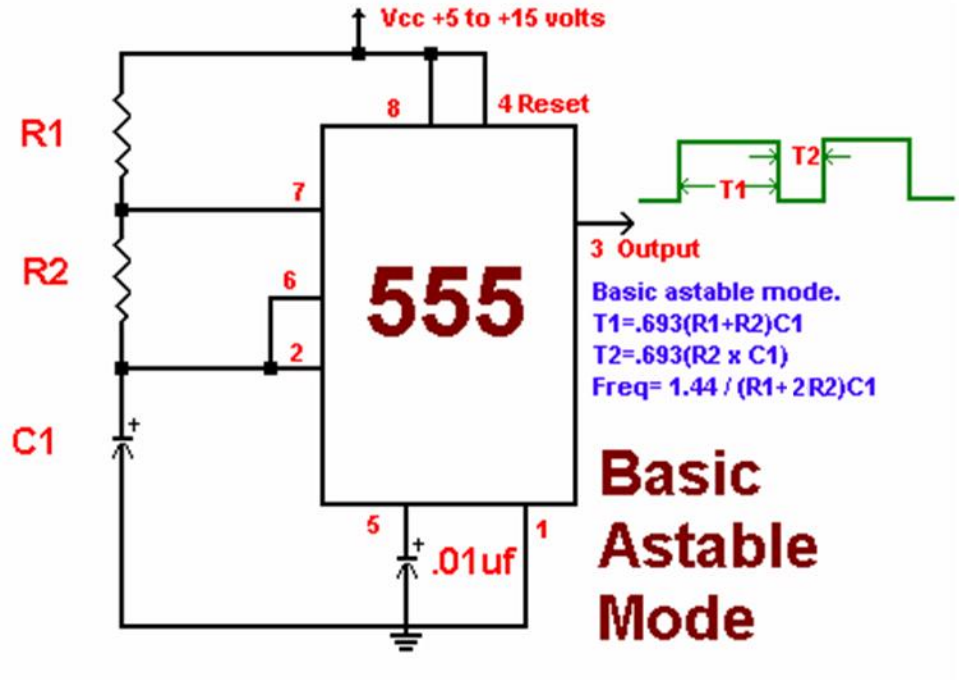


- The capacitor voltage cycles back and forth between (2/3)Vcc and (1/3)Vcc at times and $\tau_1 = 0.693(R1 + R2)C1$

$$\tau_2 = 0.693(R2)C1$$



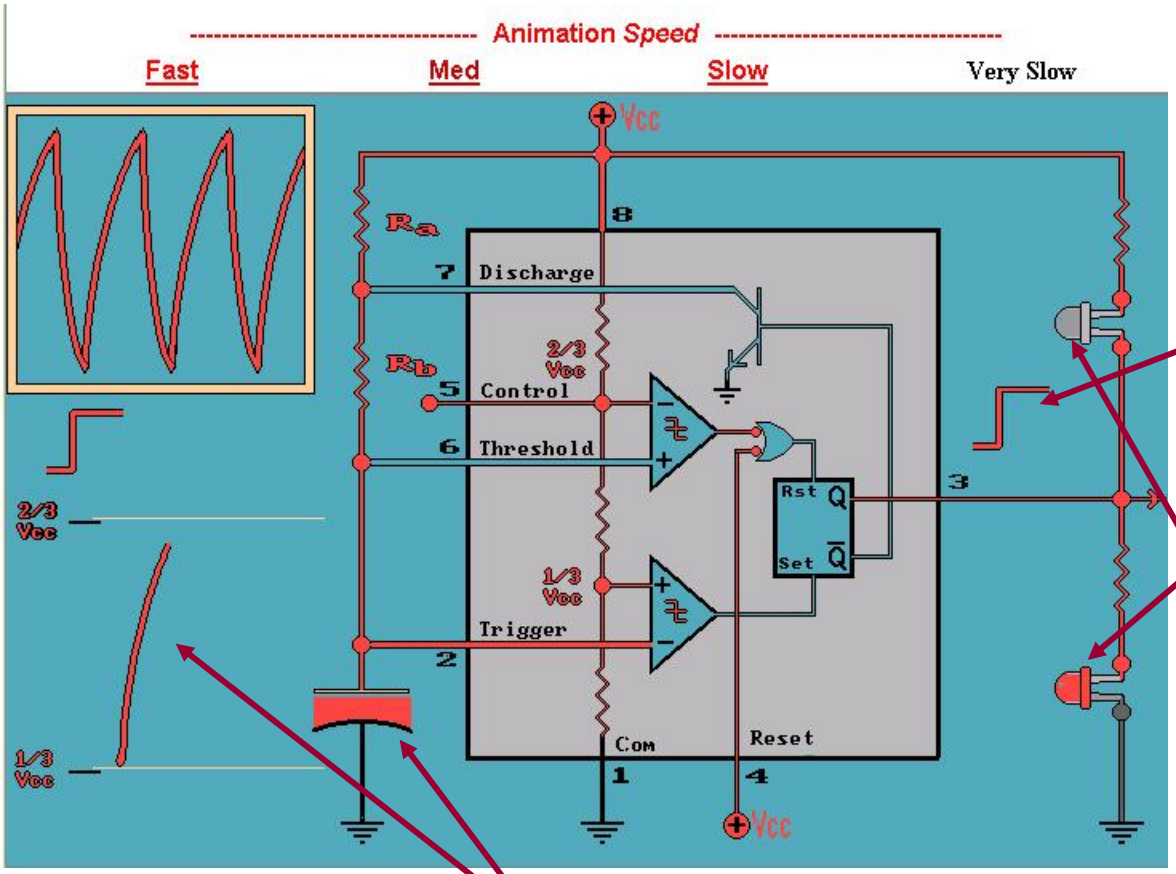
555 Timer



- The frequency is then given by

$$f = \frac{1}{0.693(R1 + 2 \cdot R2)C1} = \frac{1.44}{(R1 + 2 \cdot R2)C1}$$

555 Animation



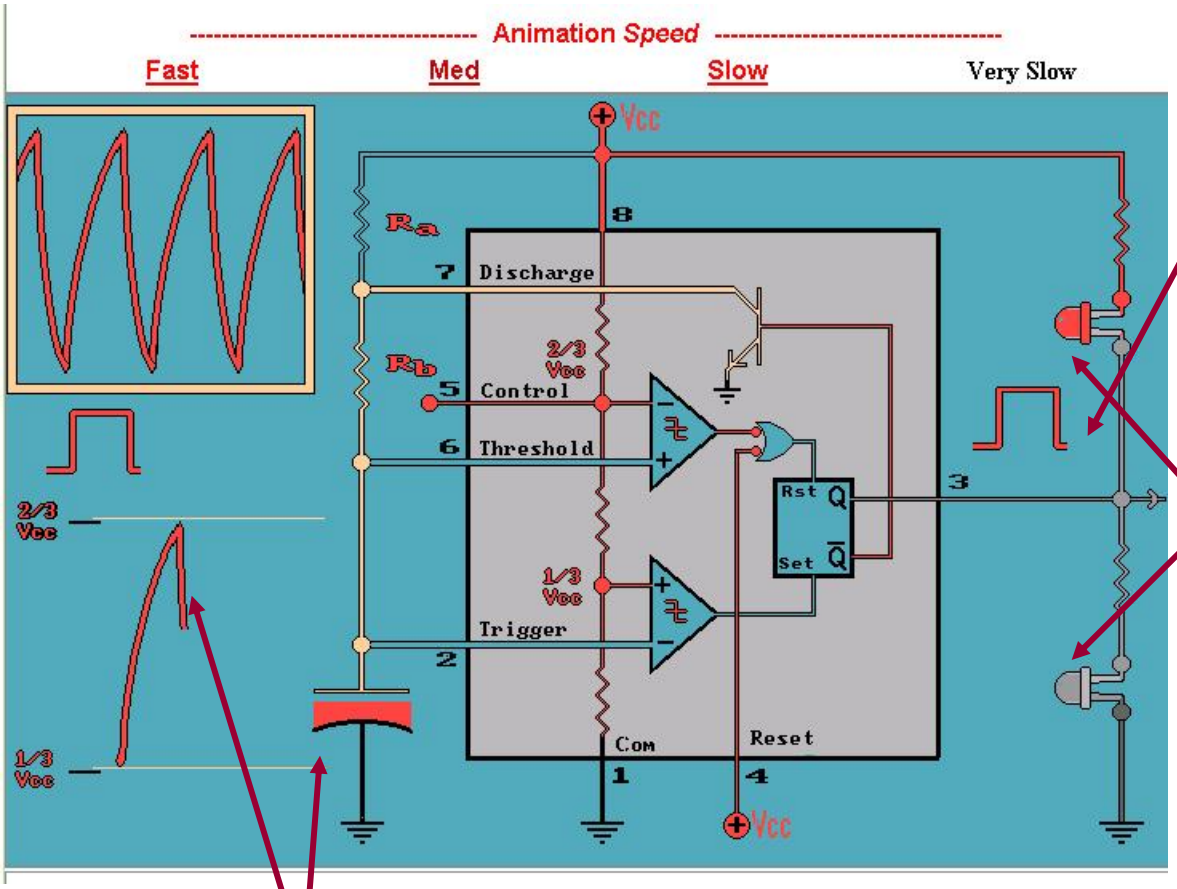
Output is high for $0.693(R_a+R_b)C$

Output voltage high turns off upper LED and turns on lower LED

Capacitor is charging through R_a and R_b

- http://www.williamson-labs.com/pu-aa-555-timer_slow.htm

555 Animation

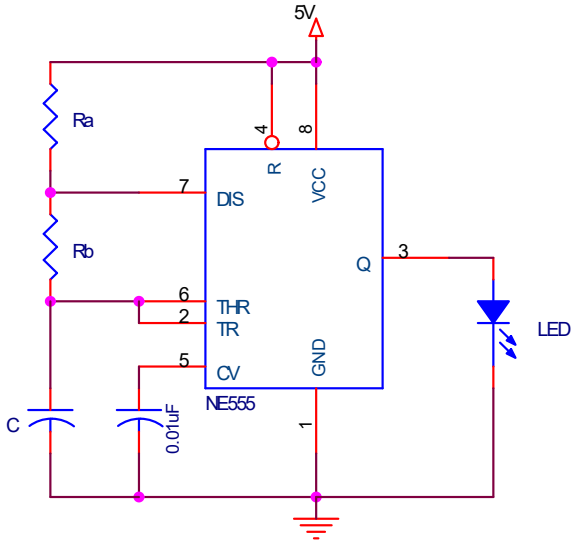


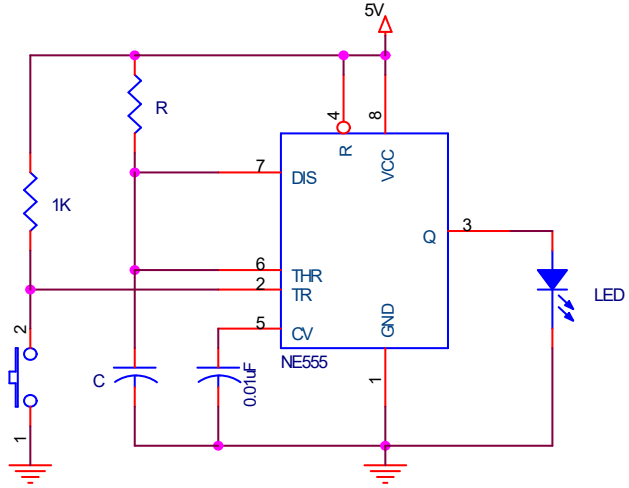
Output is low for $0.693(R_b)C$

Output is low so the upper LED is on and the lower LED is off

Capacitor is discharging through R_b

Types of 555-Timer Circuits

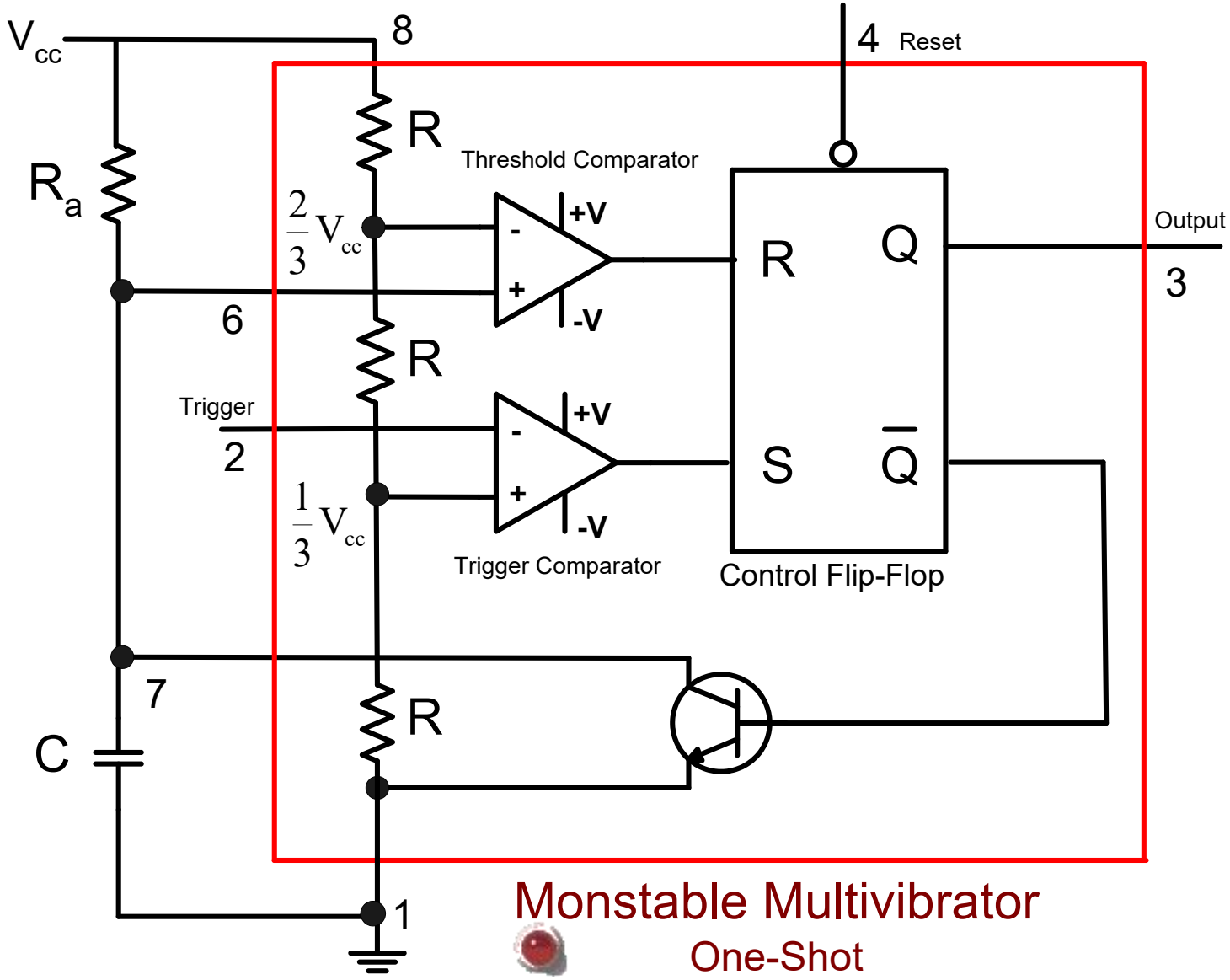




- Astable Multivibrator puts out a continuous sequence of pulses

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

Monostable Multivibrator (One Shot)

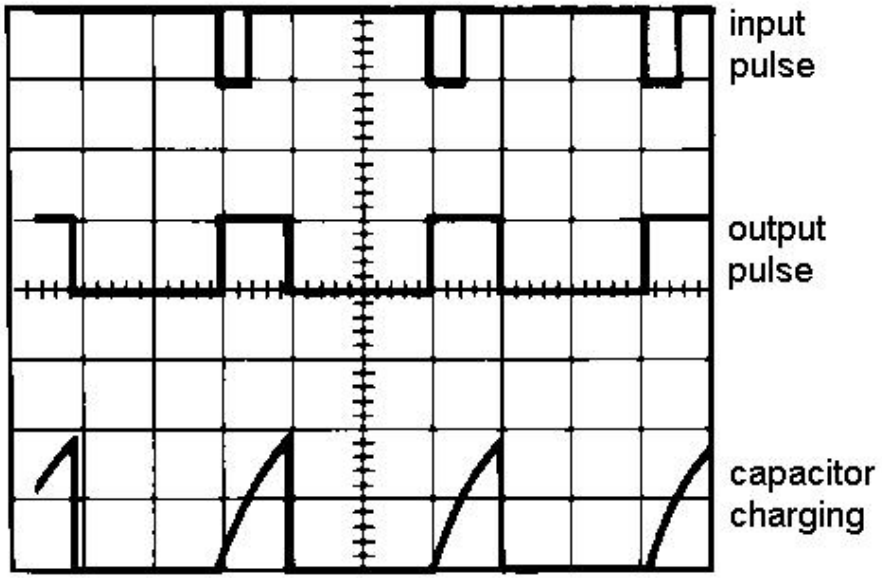


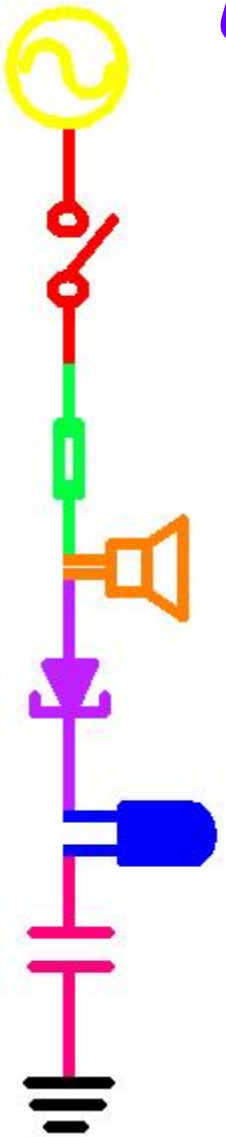
Monstable Multivibrator

One-Shot

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.

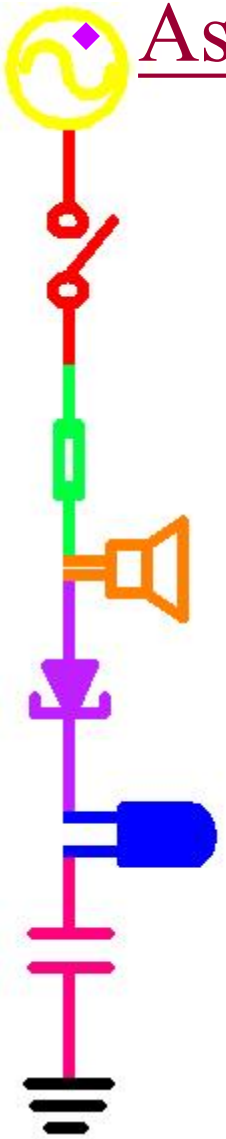


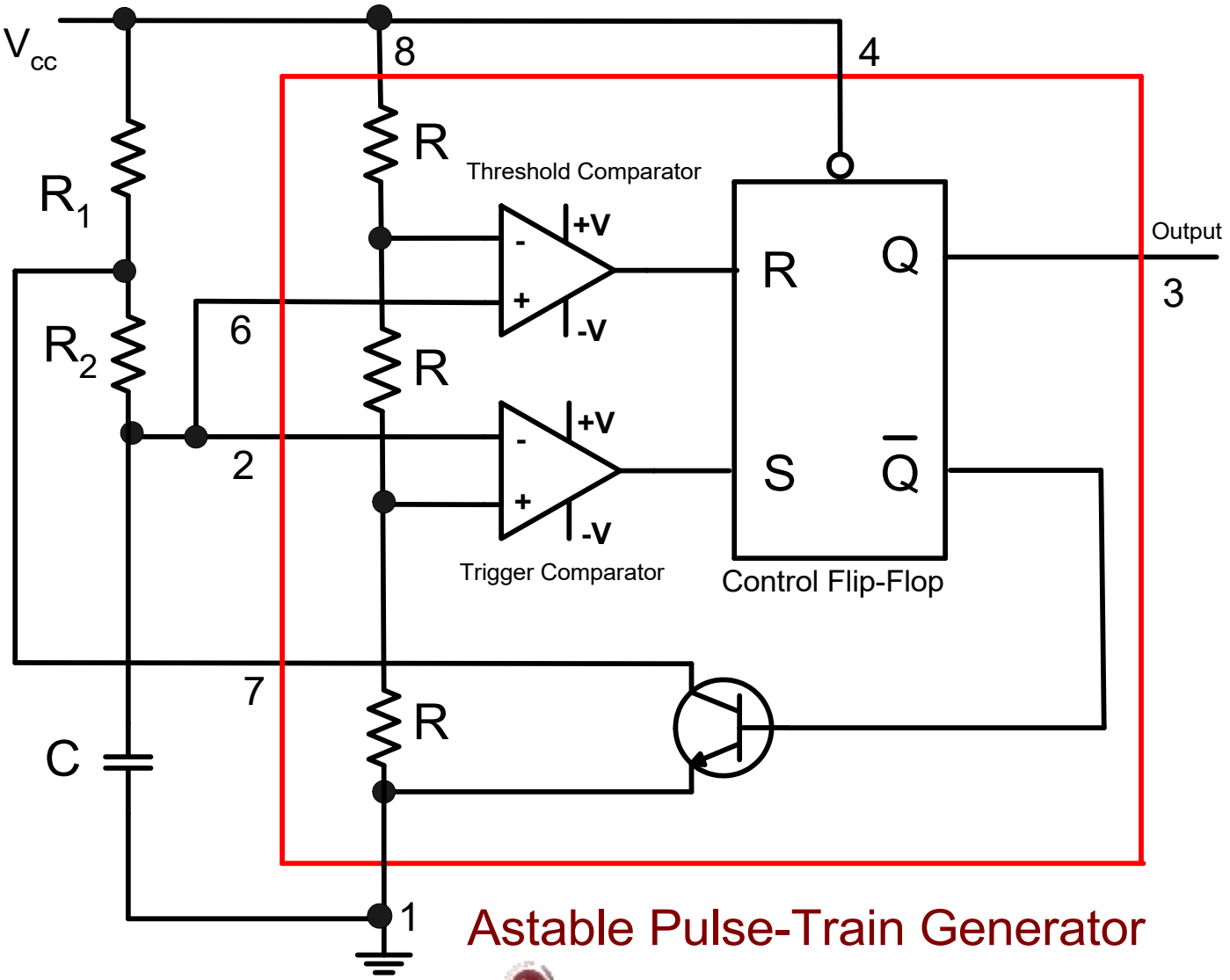


Uses of the Monostable Multivibrator

- 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.

Astable Pulse-Train Generator (Multivibrator)

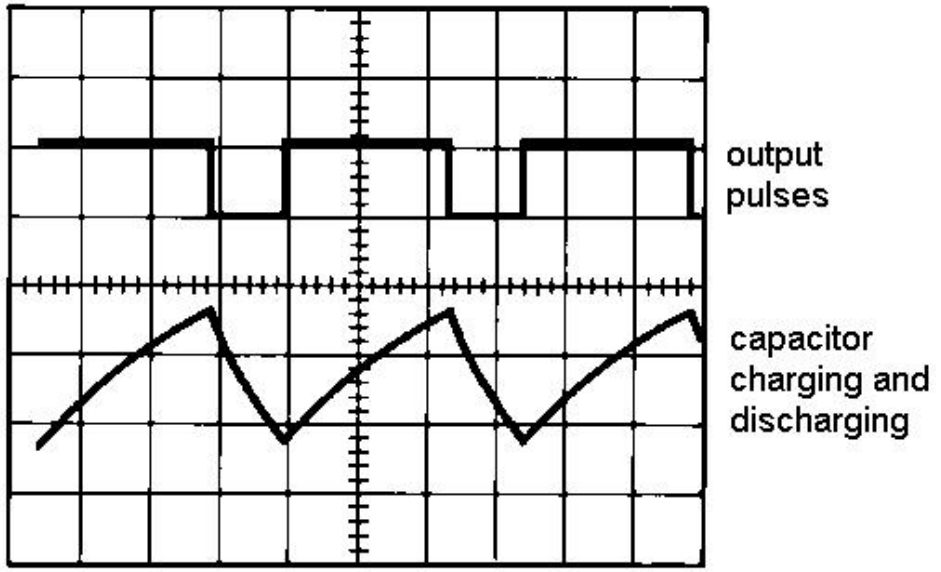




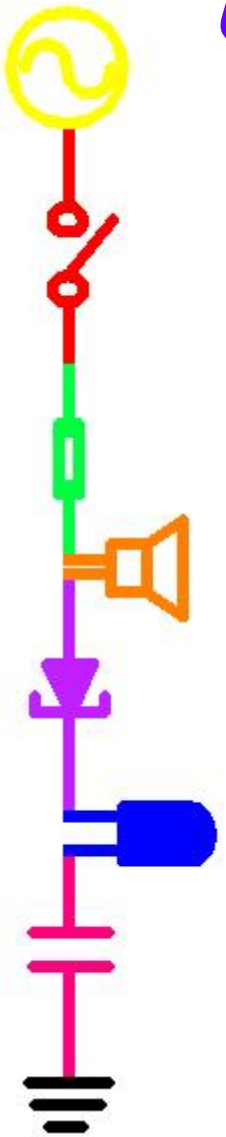
Astable Pulse-Train Generator

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_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



Uses of the Astable Multivibrator

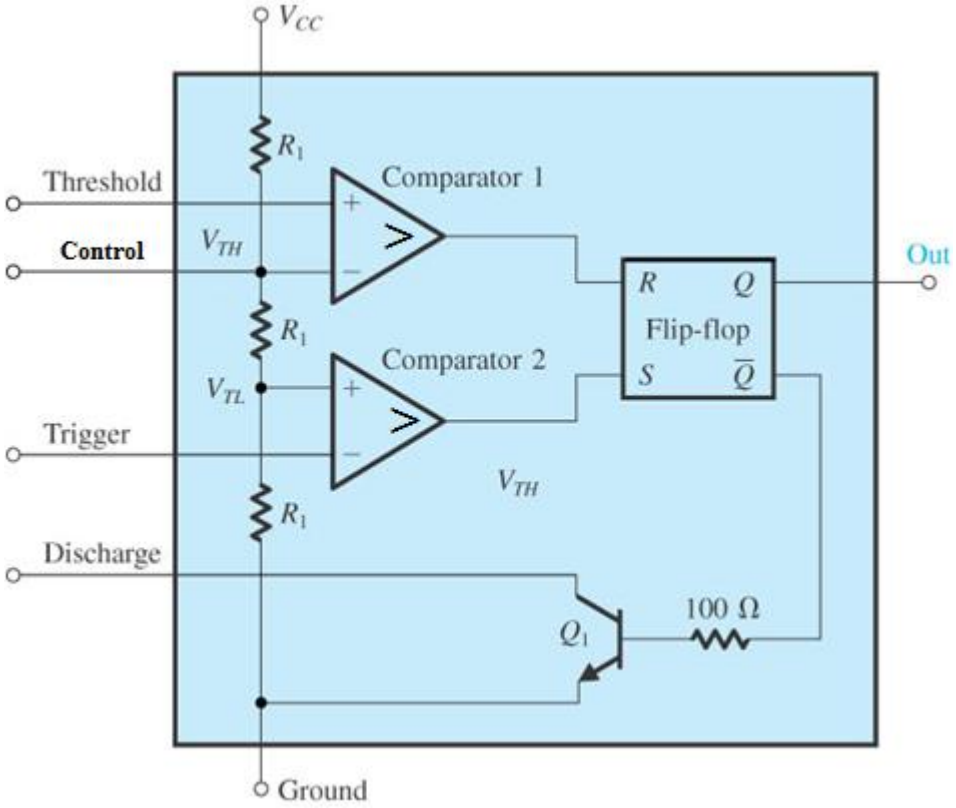


- Flashing LED's
- Pulse Width Modulation
- Pulse Position Modulation
- Periodic Timers (see mushroom timer in the experiment).

5

5

5


V_{CC}
R_1
Threshold
Comparator 1
V_{TH}
Control
Out
R
Q
Flip-flop
S
$\overline{Q}$
R_1
Comparator 2
V_{TL}
Trigger
V_{TH}
R_1
Discharge
100 Ω
Q_1
Ground

Figur

Astable

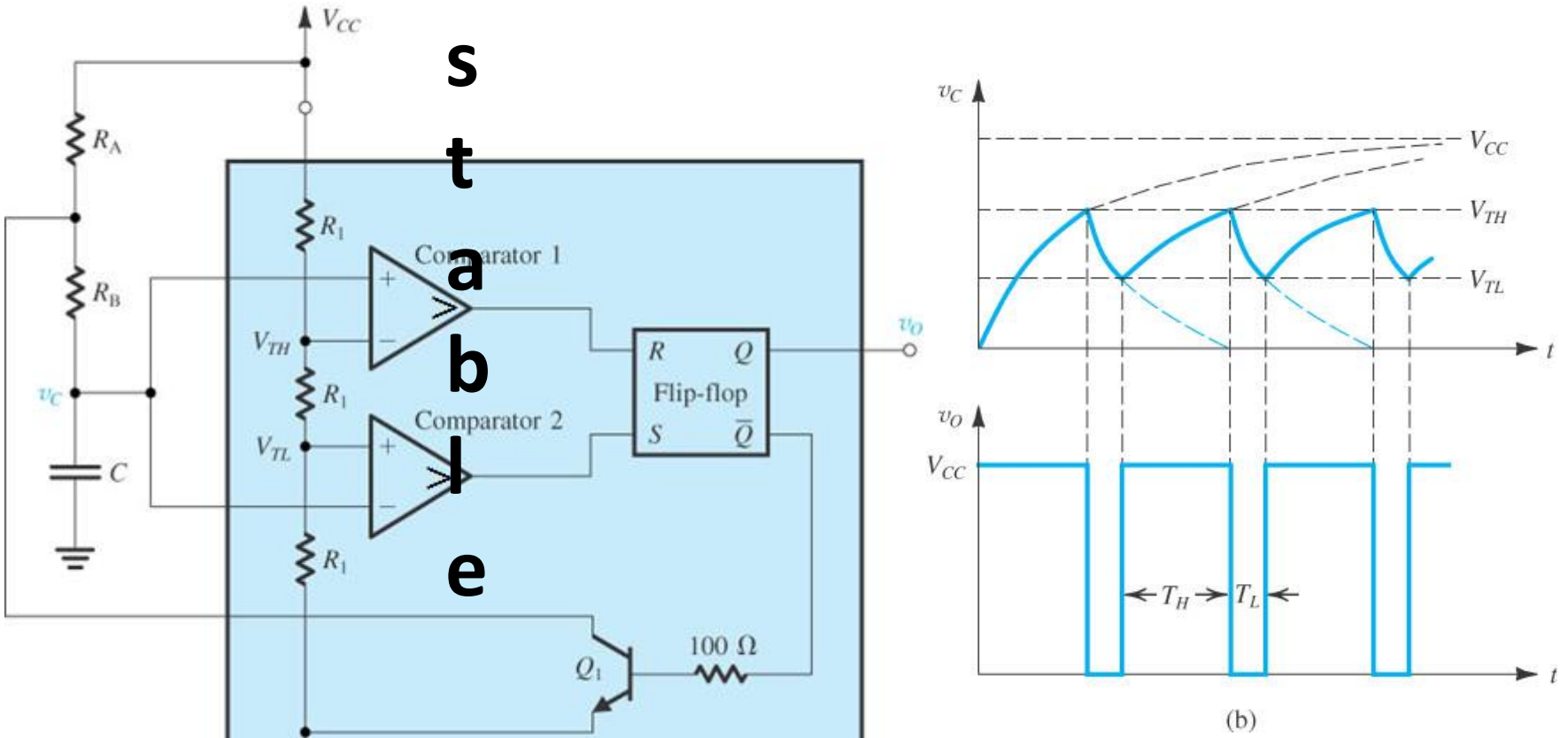


Figure 1

Monostable

$V_{control}$, varies width

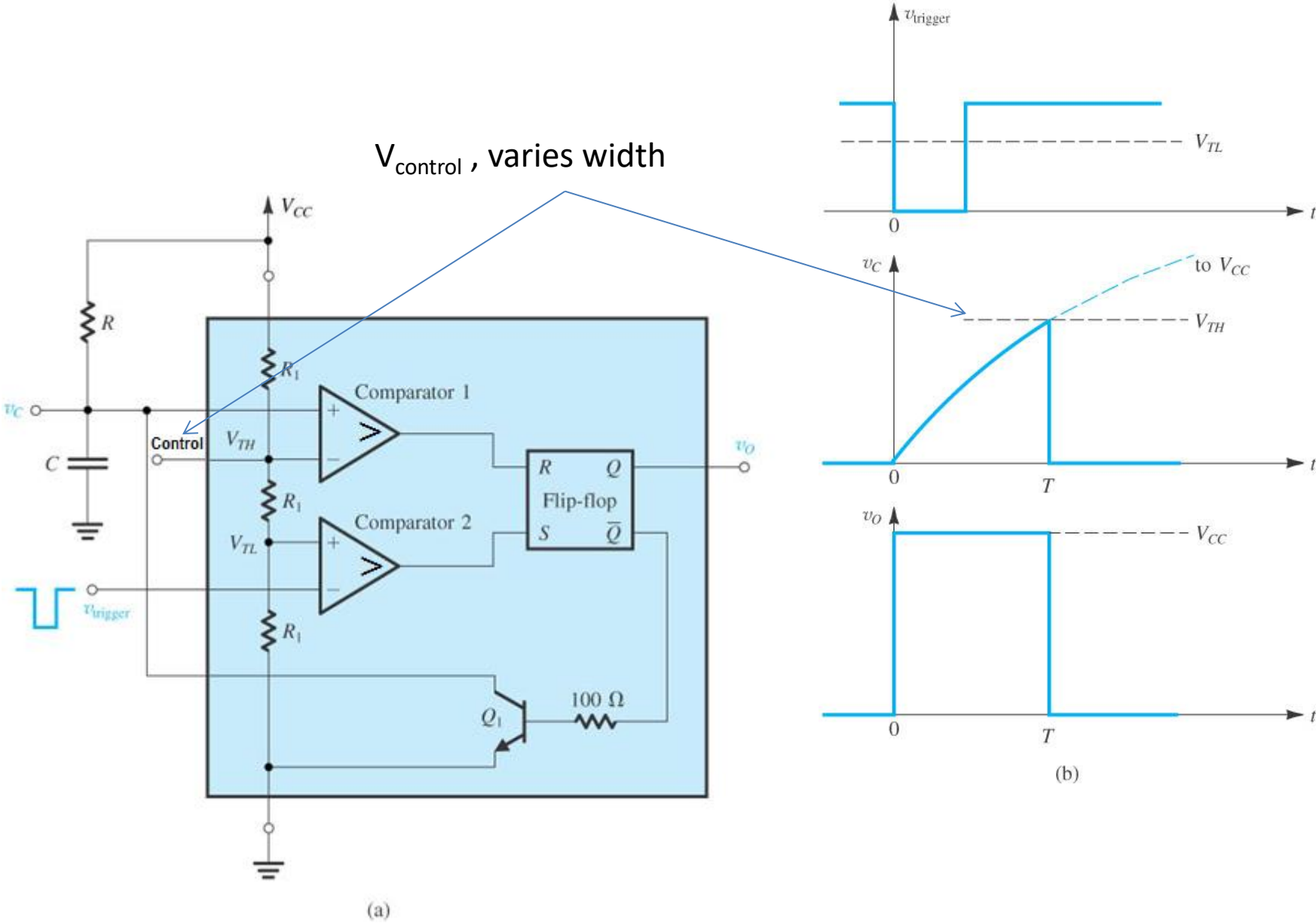


Figure 1