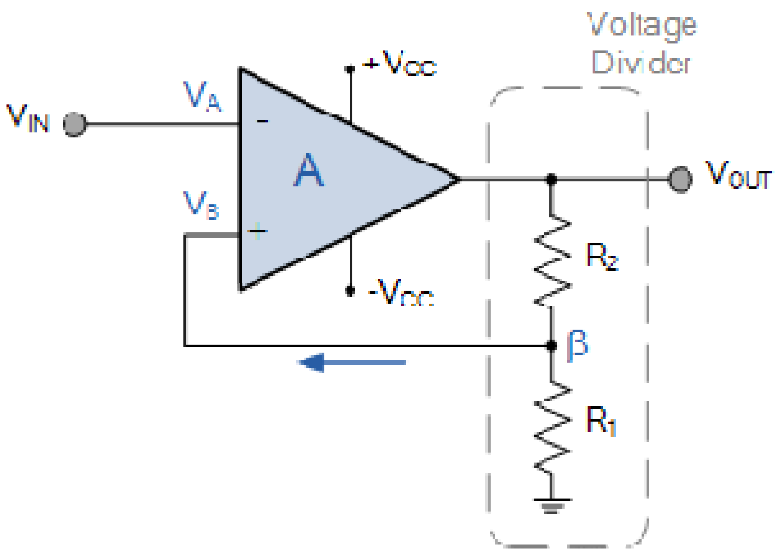
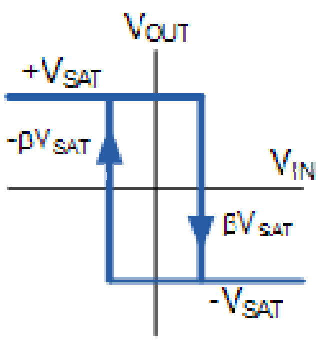
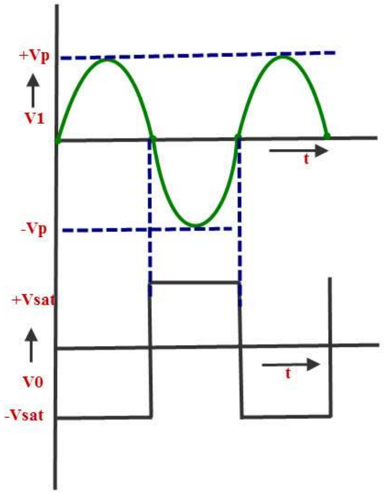
# Generation of a Square wave using Astable Multivibrator

- by connecting the bistable multivibrator with an RC circuit in a feedback loop



# Square wave Generator

The Square Wave Generator Using Op amp means the astable multivibrator circuit using op-amp, which generates the square wave of required frequency.

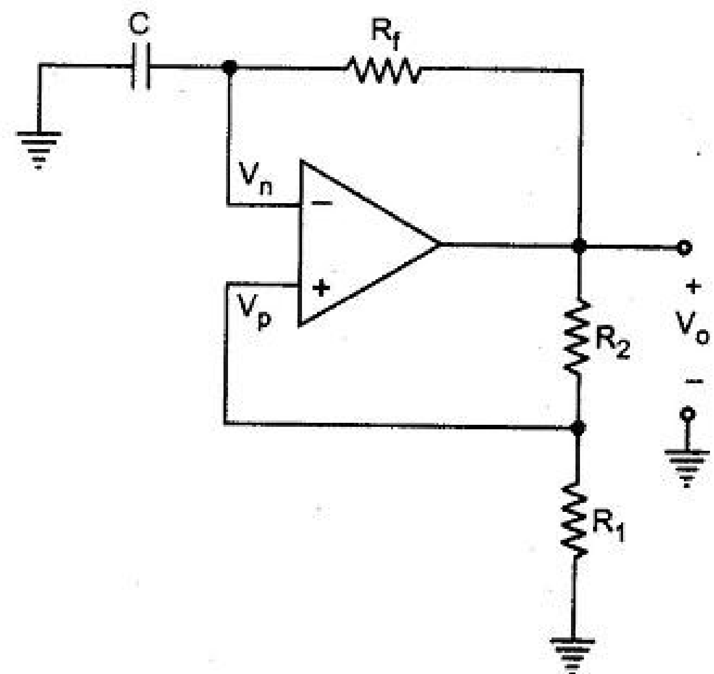
It looks like a comparator with hysteresis (schmitt trigger), except that the input voltage is replaced by a capacitor. The circuit has a time dependent elements such as resistance and capacitor to set the frequency of oscillation.

When $V_o$ is at +Vsat, the feedback voltage is called the upper threshold voltage $V_{UT}$ and is given as

$$V_{UT} = \frac{R_1 \cdot +V_{sat}}{R_1 + R_2}$$

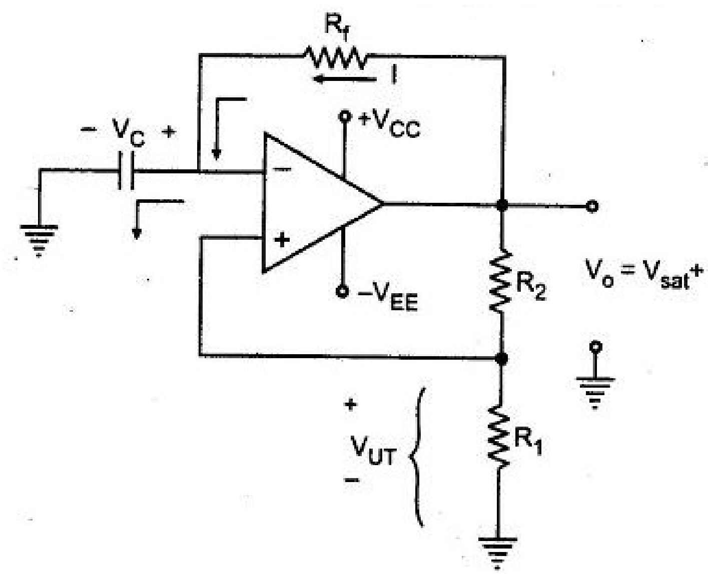
When $V_o$ is at —Vsat, the feedback voltage is called the lower-threshold voltage $V_{LT}$ and is given as

$$V_{LT} = \frac{R_1 \cdot -V_{sat}}{R_1 + R_2}$$



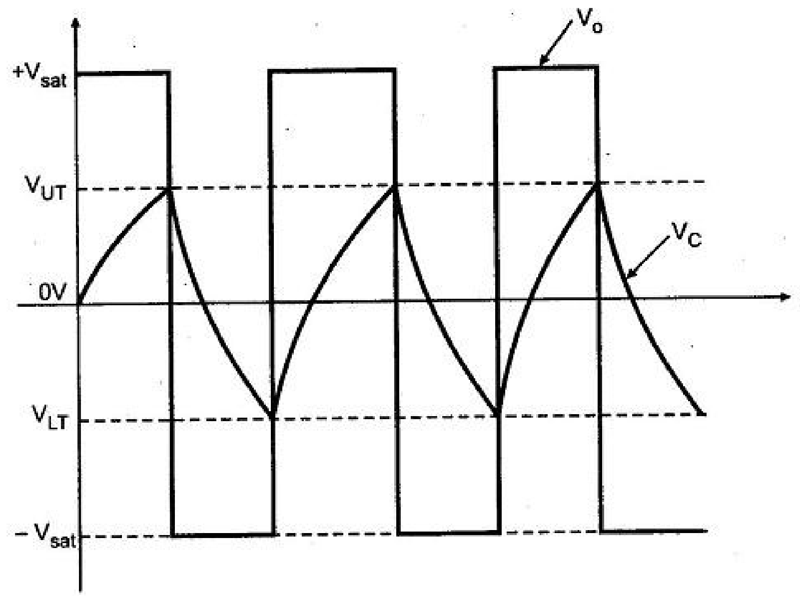
# Operation:

- When power is turn ON: $V_{out}$ automatically swings either to $+V_{sat}$ or to — $V_{sat}$ since these are the only stable states allowed by the schmitt trigger.
- Assume it swings to $+V_{sat}$ : With Vo= $+V_{sat}$ and $V_p = V_{UT}$ and capacitor starts charging towards $+V_{sat}$ through the feedback path provided by the resistor $R_f$ to the inverting (—) input.
- As long as the capacitor voltage $V_c$ is less than $V_{uT}$, the output voltage remains at +Vsat.
- As soon as $V_c$ charges to a value slightly greater than $V_{uT}$ , the (—) input goes positive with respect to the (+) input. This switches the output voltage from $+V_{sat}$ to — $V_{sat}$ and we have $V_p = V_{LT}$ which is negative with respect to ground. As $V_o$ switches to $—V_{sat}$, capacitor starts discharging via $\mathbf{R_f}$.
- The current I – discharges capacitor to 0 V and recharges capacitor to VLT. When Vc becomes slightly more negative than the feedback voltage VLT, output voltage V. switches back to $+V_{sat}$



# Waveform

- As a result, the condition is reestablished except that capacitor now has a initial charge equal to VLT.
- The capacitor will discharge from $V_{LT}$ to OV and then recharge to $V_{UT}$, and the process is repeating.
- Once the, initial cycle is completed, the waveforms become periodic.



# Frequency of Oscillations

- The frequency of oscillation is determined by the time it takes the capacitor to charge from $V_{LT}$ to $V_{UT}$ and vice versa. The voltage across the capacitor as a function of time is given as

$$V_C(t) = V_{max} + (V_{initial} - V_{max})e^{(-t/T)}$$

- where $V_c(t)$ is the instantaneous voltage across the capacitor.
- $V_{initial}$ is the initial voltage
- $V_{max}$ is the voltage toward which the capacitor is charging.

- Let us consider the charging of capacitor from $V_{LT}$ to $V_{UT}$, where $V_{LT}$ is the initial voltage, $V_{UT}$ is the instantaneous voltage and + $V_{sat}$ is the maximum voltage. At t = $T_l$, voltage across capacitor reaches $V_{UT}$ and therefore equation becomes

$$V_{UT} = +V_{sat} + (V_{LT} - +V_{sat})e^{(-T_1/R_f C)}$$

$$\therefore -(V_{LT} - +V_{sat})e^{(-T_1/R_f C)} = +V_{sat} - V_{UT}$$

$$\therefore \quad e^{(-T_1/R_f C)} = \frac{(+V_{sat} - V_{UT})}{(+V_{sat} - V_{LT})}$$

$$\frac{-T_1}{R_f C} = ln\left(\frac{+V_{sat} - V_{UT}}{+V_{sat} - V_{LT}}\right)$$

$$T_1 = -R_f C\, ln\left(\frac{+V_{sat} - V_{UT}}{+V_{sat} - V_{LT}}\right)$$

$$= R_f C\, ln\left(\frac{+V_{sat} - V_{LT}}{+V_{sat} - V_{UT}}\right)$$

- The time taken by capacitor to charge from $V_{UT}$ to $V_{LT}$ is same as time required for charging capacitor from $V_{LT}$ to $V_{UT}$. Therefore, total time required for one oscillation is given as

$$V_{LT} = +\beta V_{sat}$$

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

$$T = 2T_1$$

$$= 2R_f\, C\, ln\left(\frac{+V_{sat} - V_{LT}}{+V_{sat} - V_{UT}}\right)$$

$$T = 2R_f C \ln\left(\frac{1+\beta}{1-\beta}\right)$$

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

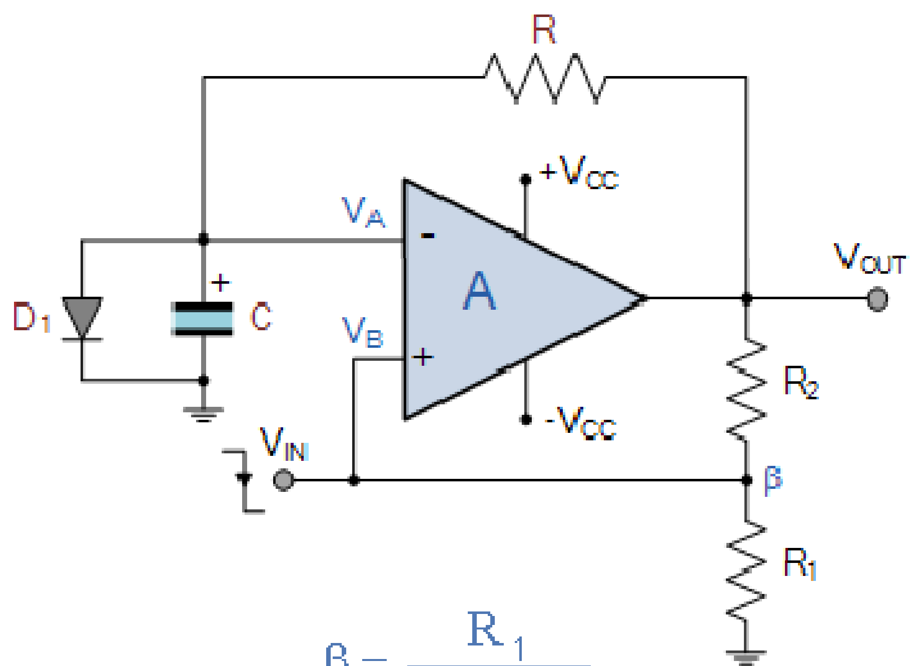
- The frequency of oscillation can be determined as $f_o$= 1/T, where T represents the time required for one oscillation.
- Substituting the value of T we get,

$$f_o = \frac{1}{2\, R_f\, C\, ln\left(\frac{+V_{sat} - V_{LT}}{+V_{sat} - V_{UT}}\right)}.$$

$$f_o = \frac{1}{2R_f C \ln\left(\frac{1+\beta}{1-\beta}\right)}$$

# Monostable Multivibrator

- At initial power on (that is t = 0), the output ($V_{OUT}$) will saturate towards either the positive rail (+Vcc), or to the negative rail (-Vcc), since these are the only two stable states allowed by the op-amp.
- Lets assume for now that the output has swung towards the positive supply rail, $+V_{cc}$. Then the voltage at the non-inverting input, $V_B$ will be equal to +Vcc*β where β is the feedback fraction.
- The inverting input is held at 0.7 volts, the forward volt drop of diode, $D_1$ and clamped to 0v (ground) by the diode, preventing it from going any more positive. Thus the potential at $V_A$ is much less than that at $V_B$ and the output remains stable at +Vcc.
- At the same time, the capacitor, (C) charges up to the same 0.7 volts potential and is held there by the forward-biased voltage drop of the diode.

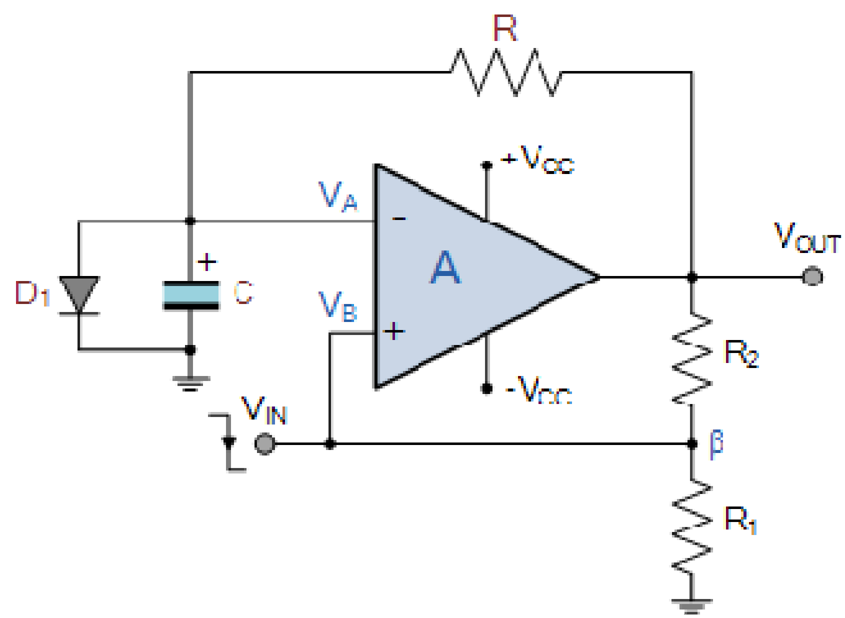



$$\beta = \frac{R_1}{R_1 + R_2}$$

# Monostable Multivibrator

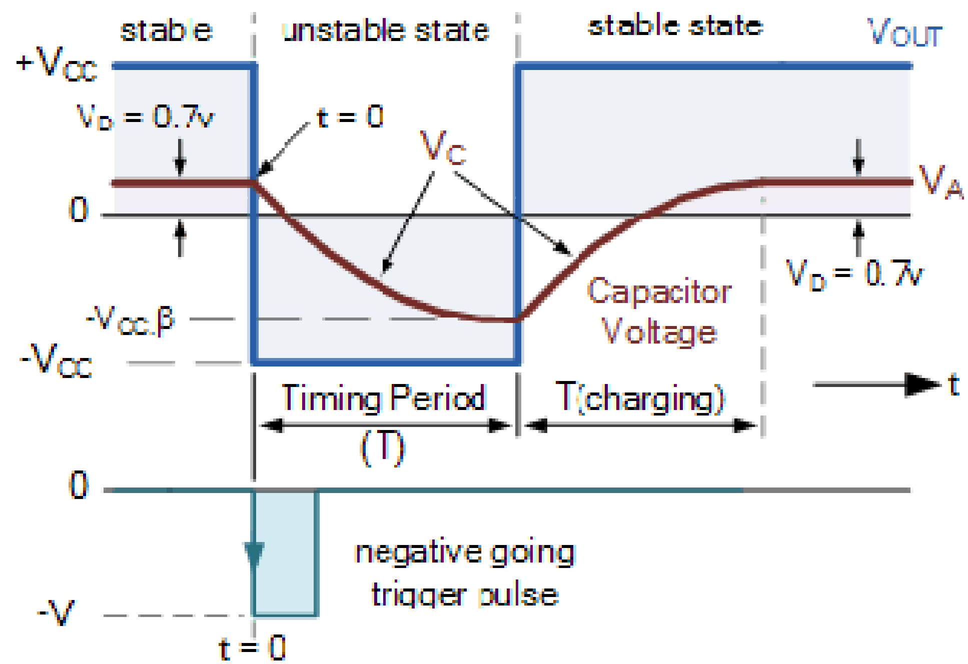
- If we were to apply a negative pulse to the non-inverting input, the 0.7v voltage at $V_A$ now becomes greater than the voltage at $V_B$ since $V_B$ is now negative. Thus the output of the Schmitt configured op-amp switches state and saturates towards the negative supply rail, -Vcc. The result is that the potential at $V_B$ is now equal to -Vcc*β.
- This temporary meta-stable state causes the capacitor to charge up exponentially in the opposite direction through the feedback resistor, R from +0.7 volts down to the saturated output which it has just switched too, -Vcc. Diode, $D_1$ becomes reverse-biased so has no effect. The capacitor, C will discharge at a time constant $\tau = RC$.
- As soon as the capacitor voltage at $V_A$ reaches the same potential as $V_B$, that is

-Vcc*β, the op-amp switches back to its original permanent stable state with the output saturated once again at $+V_{cc}$.



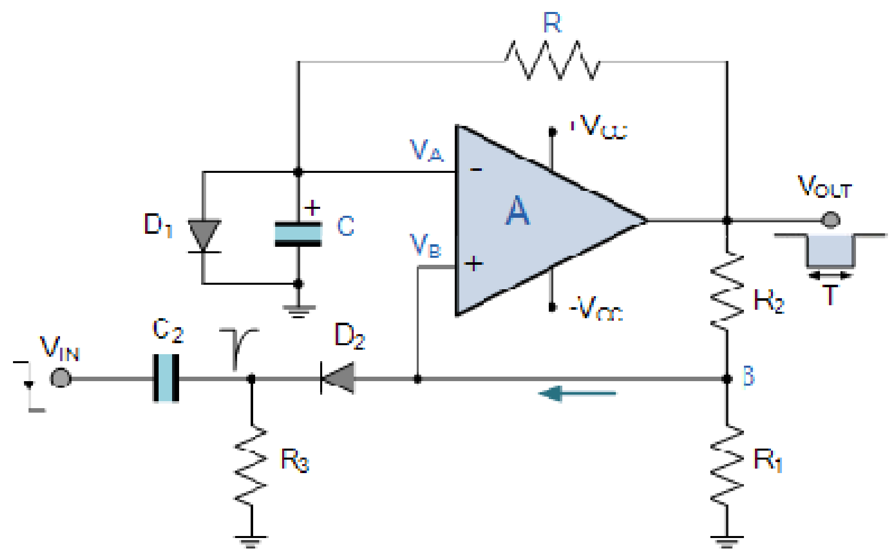
# Waveform

- Note that once the timing period is complete and the op-amps output changes back to its stable state and saturates towards the positive supply rail, the capacitor tries to charge up in reverse to +Vcc but can only charge to a maximum value of 0.7v given by the diodes forward voltage drop. We can show this effect graphically as:
- Then we can see that a negative-going trigger input, will switch the op-amp monostable circuit into its temporary unstable state. After a time delay, T while the capacitor, C charges up through the feedback resistor, R, the circuit switches back to its normal stable state once the capacitor voltage reaches the required potential.



# With RC differentiator circuit

- The advantage of using a differentiator circuit is that any constant DC voltage or slowly varying signal will be blocked allowing only rapidly varying trigger pulses to initiate the monostable timing period. Diode, D ensures that the trigger pulse arriving at the op-amps non-inverting input is always negative.
- Generally for a RC differentiator circuit, the peak value of the negative spike is approximately equal to the magnitude of the trigger waveform. Also, as a general rule-of-thumb, for an RC differentiator circuit to produce good sharp narrow spikes, the time constant, ( τ ) should be at least ten times smaller than the input pulse width.



# Time Period

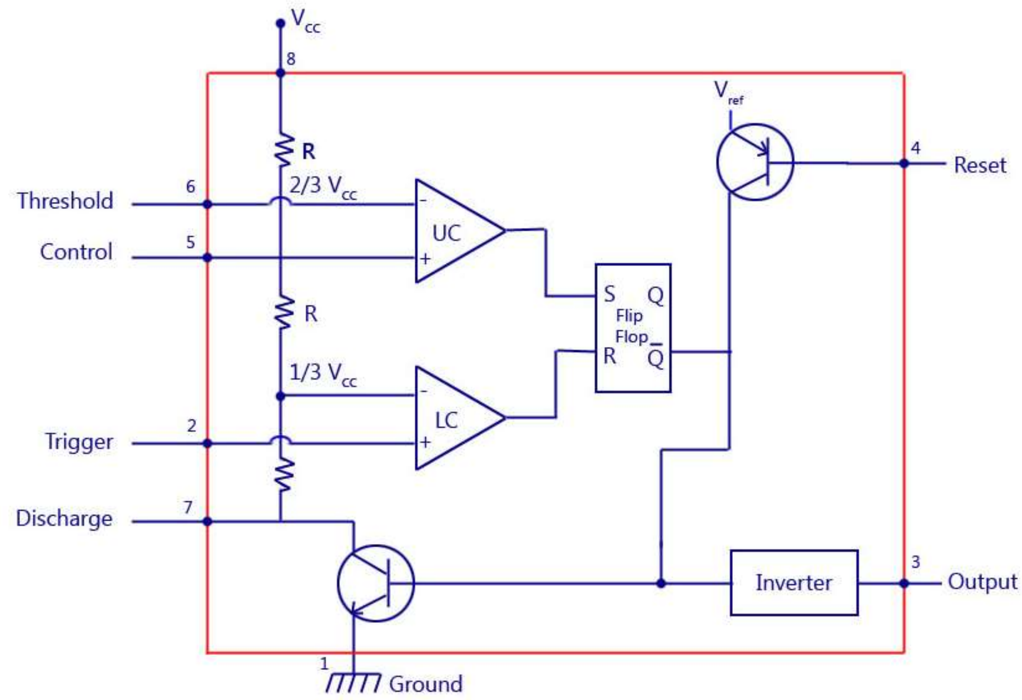
- Solution for single time constant RC circuit, $v_o = V_f + \left(V_i - V_f\right)e^{-t/RC}$
- For the circuit, $V_f$ = - $V_{sat}$, and $V_i$ = $V_D$; $v_c = -V_{sat} + \left(V_D + V_{sat}\right)e^{-t/RC}$
- At t = T $v_c = -\beta V_{sat}$ then $-\beta V_{sat} = -V_{sat} + \left(V_D + V_{sat}\right)e^{-T/RC}$
- Pulse width T

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

- If, $V_{sat}$ >> $V_D$ $R_1$ = $R_2$ so that β = 0.5, $T = 0.69RC$

# 555 Timer

- The circuit consists of two comparators, an SR flip-flop, and a transistor $Q1$ that operates as a switch. One power supply ($VCC$) is required for operation.
- A resistive voltage divider, consisting of the three equal-valued resistors labeled $R_1$, is connected across $V_{CC}$ and establishes the reference (threshold) voltages for the two comparators. These are $V_{TH}$ = 2/3 $V_{CC}$ for comparator 1 and $V_{TL}$ = 1/3$V_{CC}$ for comparator 2.



- Here note that an SR flip-flop is a bistable circuit having complementary outputs, denoted $Q$ and $\bar{Q}$ . In the *set* state, the output at $Q$ is "high" (approximately equal to $V_{CC}$) and that at $\bar{Q}$ is "low" (approximately equal to 0 V).
- In the other stable state, termed the *reset* state, the output at $Q$ is low and that at $\bar{Q}$ is high. The flip-flop is set by applying a high level ($V_{CC}$) to its set input terminal, labeled $S$. To reset the flip-flop, a high level is applied to the reset input terminal, labeled $R$. Note that the reset and set input terminals of the flip-flop in the 555 circuit are connected to the outputs of comparator 1 and comparator 2, respectively.
- The positive-input terminal of comparator 1 is brought out to an external terminal of the 555 package, labeled Threshold. Similarly, the negative-input terminal of comparator 2 is connected to an external terminal labeled Trigger, and the collector of transistor $Q1$ is connected to a terminal labeled Discharge.