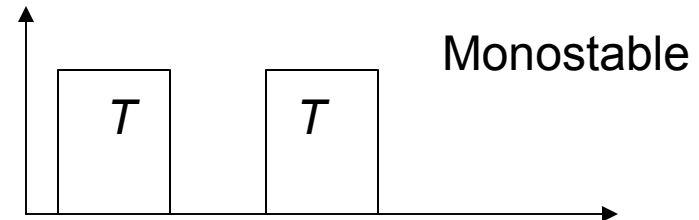
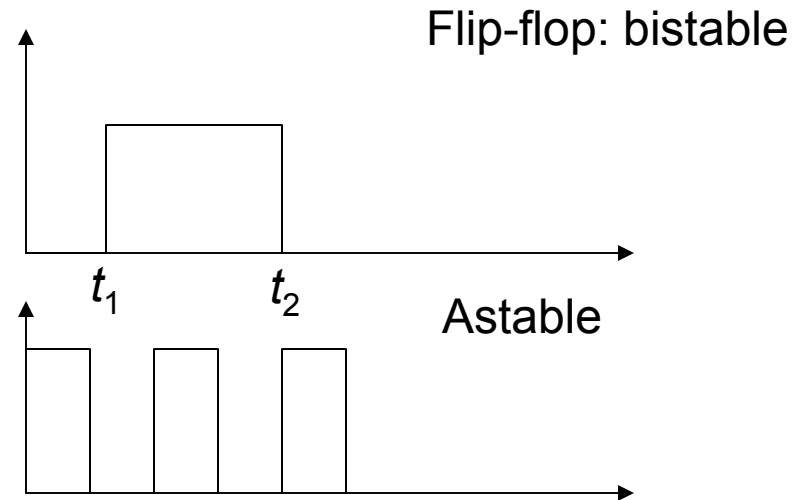
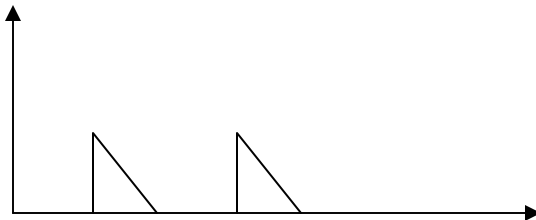
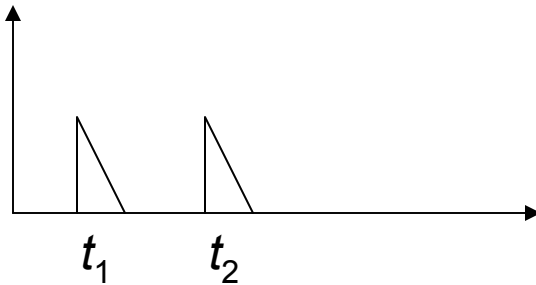


# Generation of Square and Rectangular Waveforms Using Astable Multivibrators

A square waveform can be generated by arranging for a bistable multivibrator to switch states periodically. This can be done by connecting the bistable multivibrator with an *RC* circuit in a feedback loop.

- The monostable multivibrator generates an output of predetermined duration in response to a short trigger at the input. This duration is set by the values of certain timing components in the circuit.
- The astable multivibrator produces a rectangular waveform at the output and requires no input signal. The frequency of the output signal is determined by the values of certain timing components in the circuit.

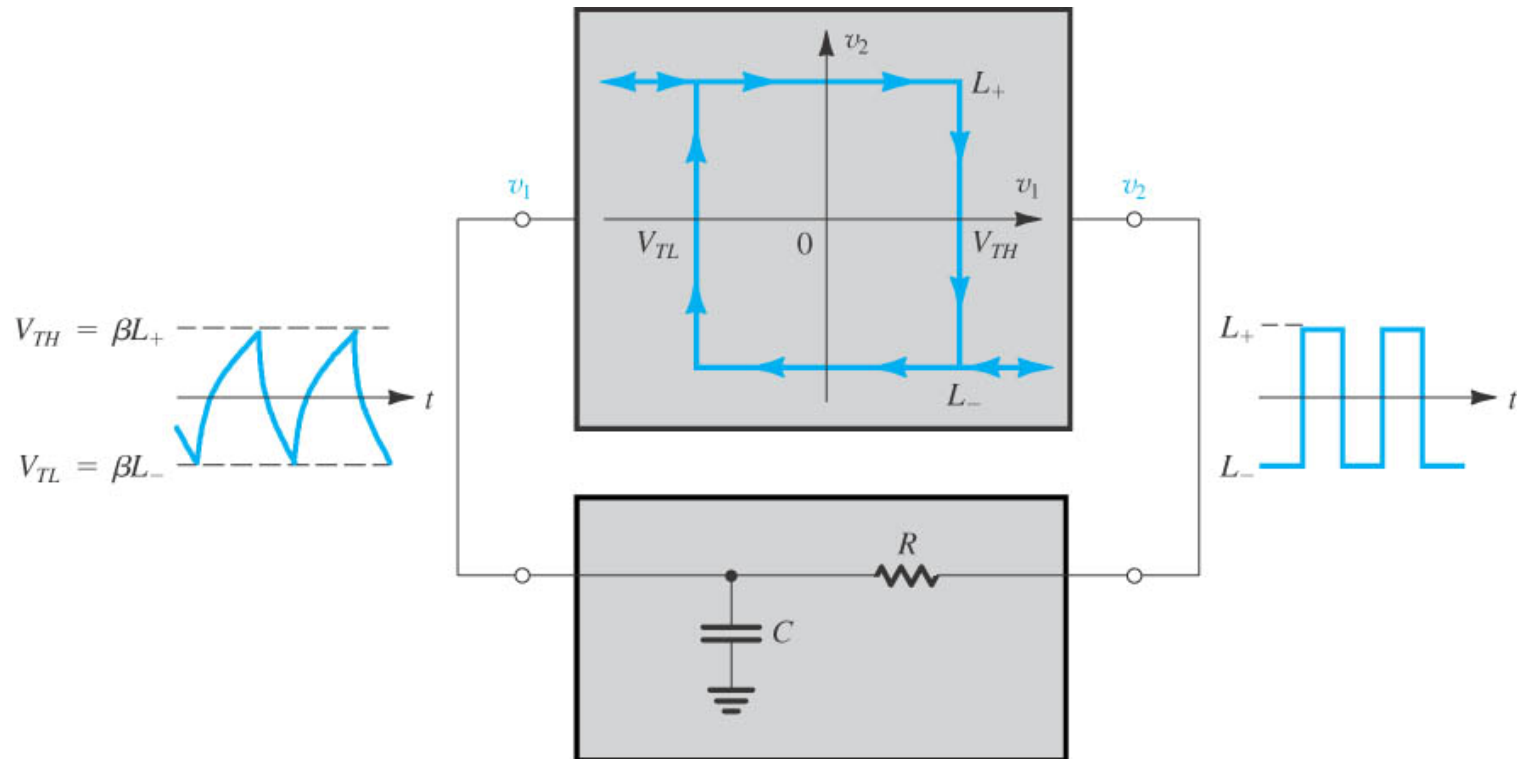
# Multivibrator Waveforms



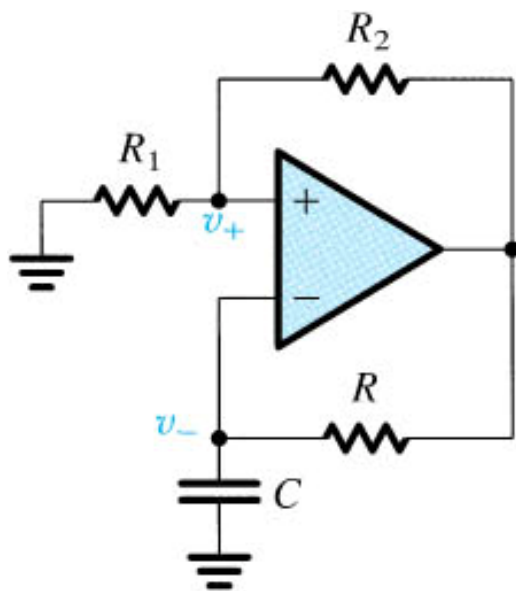
# Operation of the Astable Multivibrator

A type of multivibrator circuit employs a combination of positive and negative feedback and generates rectangular waveform. The output of the circuit has no stable state and is referred an astable circuit.

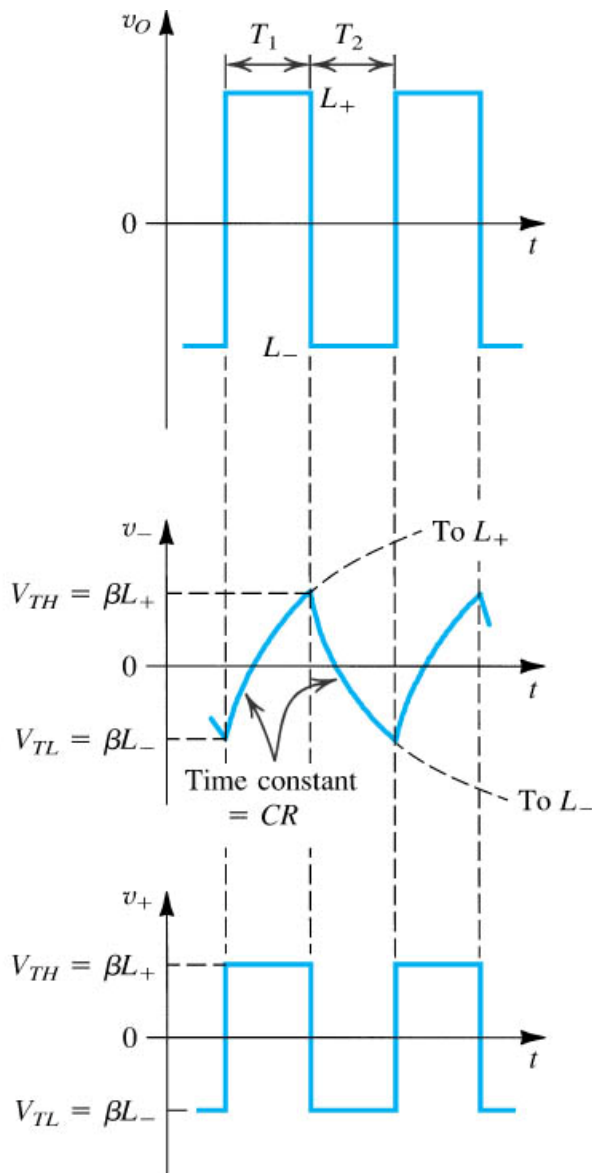
Bistable multivibrator



(a)



(b)



(c)

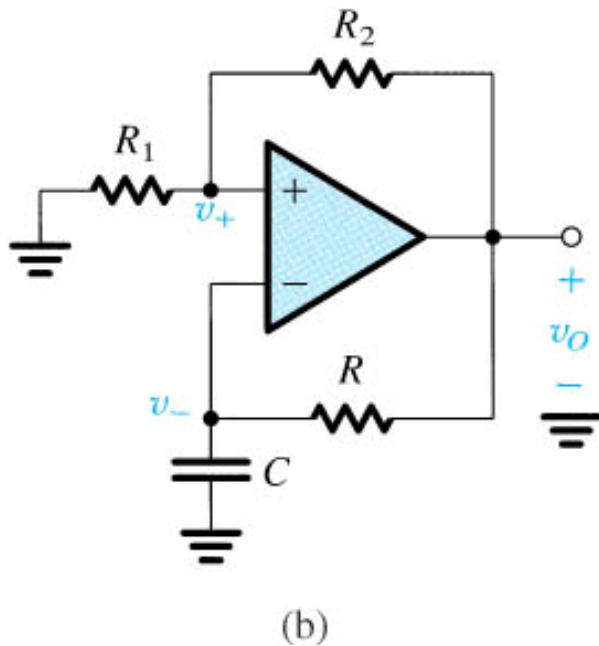
$$v_- = L_+ - (L_+ - \beta L_-)e^{-t/\tau}$$

$$v_- = L_- - (L_- - \beta L_+)e^{-t/\tau}$$

$$T = T_1 + T_2$$

$$T = 2\tau \ln \frac{1+\beta}{1-\beta}$$

**Exercise 13.16:** Let the op amp saturation voltages be  $\pm 10$  V,  $R_1 = 100$  k $\Omega$ ,  $R_2 = R = 1$  M $\Omega$  and  $C = 0.01$   $\mu$ F. Find the frequency of oscillation

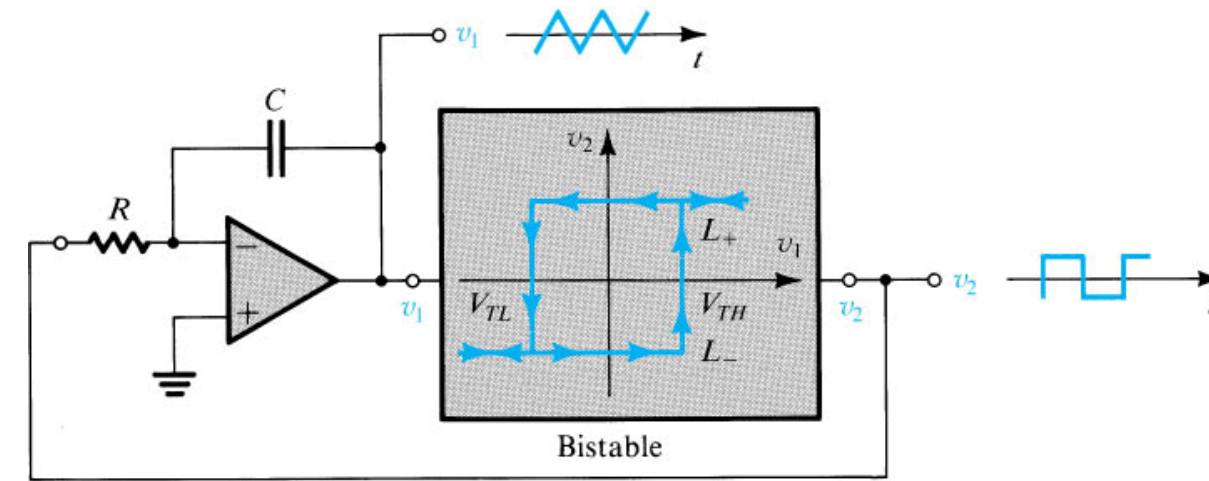


$$\beta = \frac{R_1}{R_1 + R_2} = \frac{100}{100 + 1000} = 0.091$$

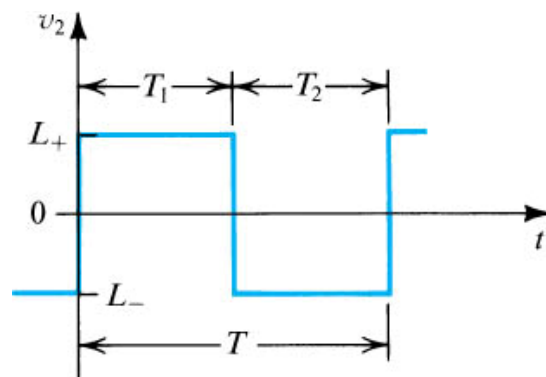
$$T = 2\tau \ln \frac{1 + \beta}{1 - \beta} = 0.00365 \text{ s}$$

$$f = \frac{1}{T} = 274 \text{ Hz}$$

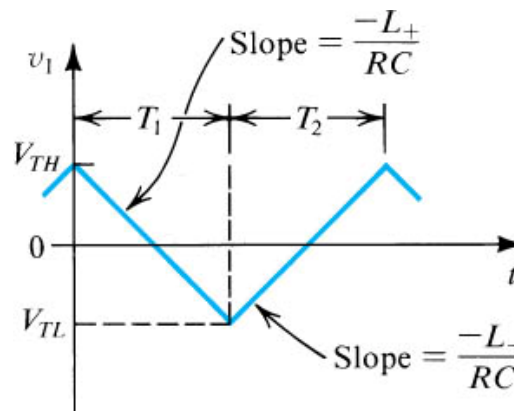
# Generation of Triangular Waveforms



(a)



(b)



(c)

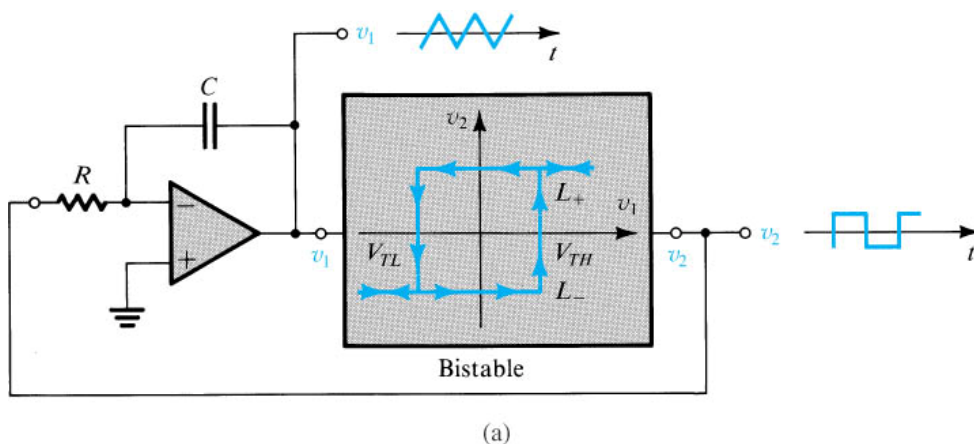
$$\frac{V_{TH} - V_{TL}}{T_1} = \frac{L_+}{CR}$$

$$T_1 = CR \frac{V_{TH} - V_{TL}}{L_+}$$

$$\frac{V_{TH} - V_{TL}}{T_2} = \frac{-L_-}{CR}$$

$$T_2 = CR \frac{V_{TH} - V_{TL}}{-L_-}$$

**Exercise 3.18:** Consider the following bistable circuit. If the op amp has a saturation voltages of  $\pm 10$  V and if  $C = 0.01\mu\text{F}$  and  $R_1 = 10$  k $\Omega$ . Find the values of  $R$  and  $R_2$  such that the frequency of oscillation is 1 kHz and the triangle waveform has a 10-V peak-to-peak amplitude..



$$V_{TH} = -V_{TL} = 5 \text{ V}$$

$$V_{TL} = -L + \frac{R_1}{R_2}$$

$$-5 = -10 \times \frac{10}{R_2}; R_2 = 20 \text{ k}\Omega$$

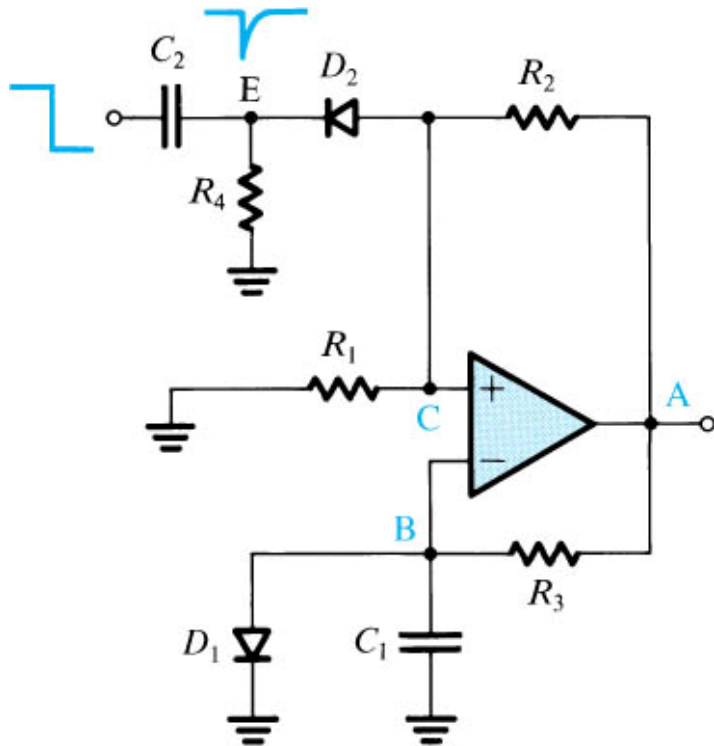
$$\text{For } 1 \text{ kHz, } T = 1 \text{ ms}$$

$$\frac{T}{2} = 0.5 \times 10^{-3} = CR \frac{V_{TH} - V_{TL}}{L +}$$

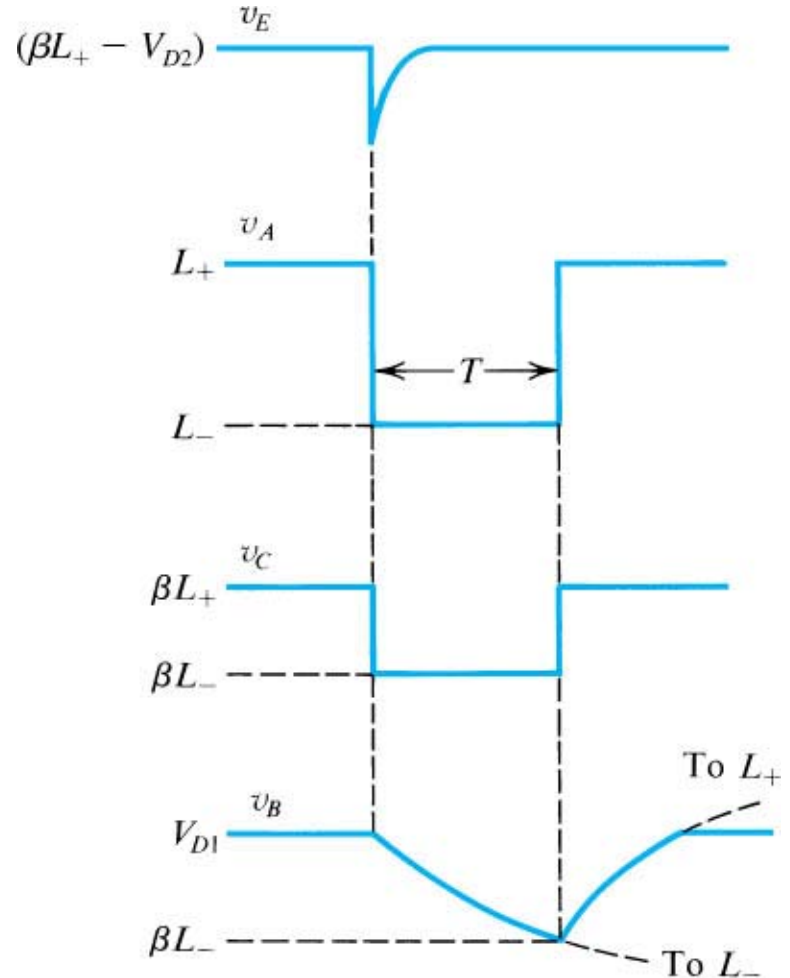
$$R = 50 \text{ k}\Omega$$

# Generation of a Standardized Pulse

The Monostable Multivibrator or One Shot



(a)

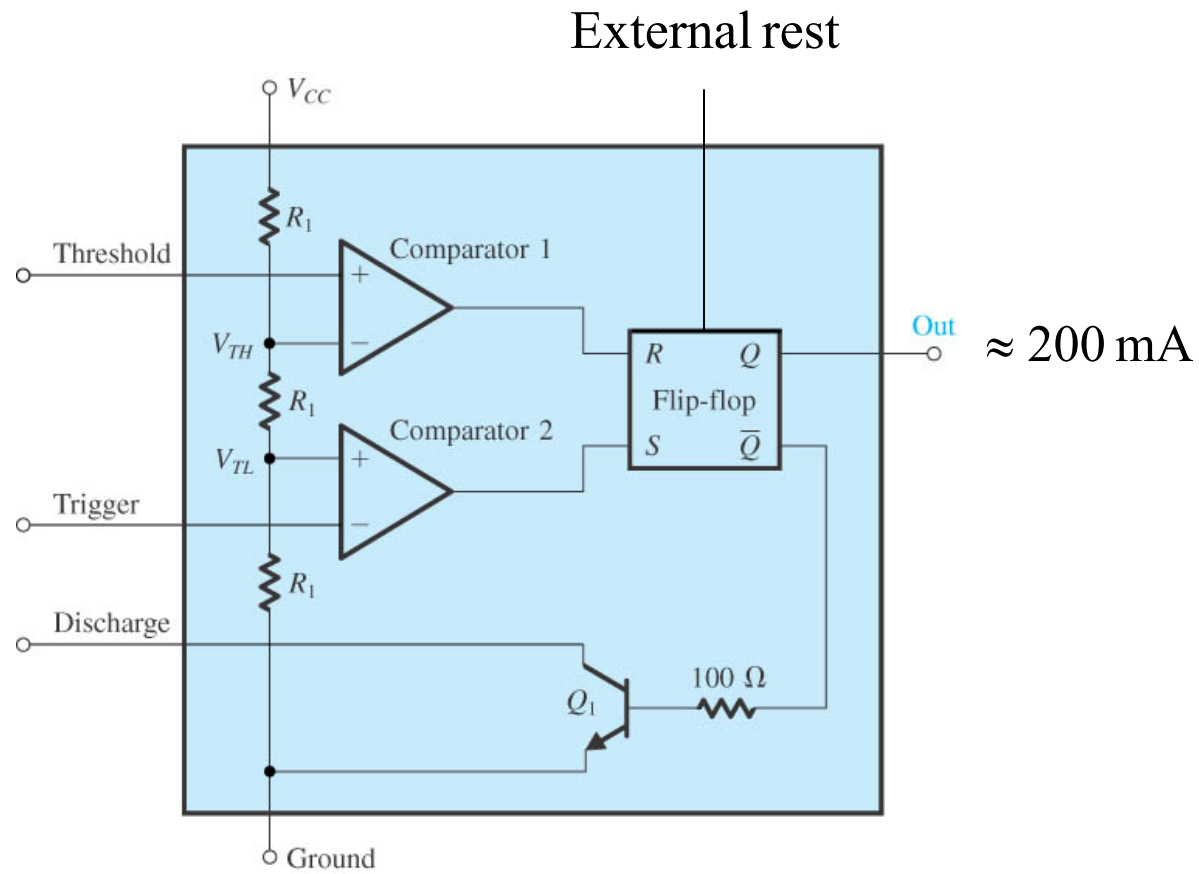


(b)



## Integrated-Circuit Timers: The 555 Circuit

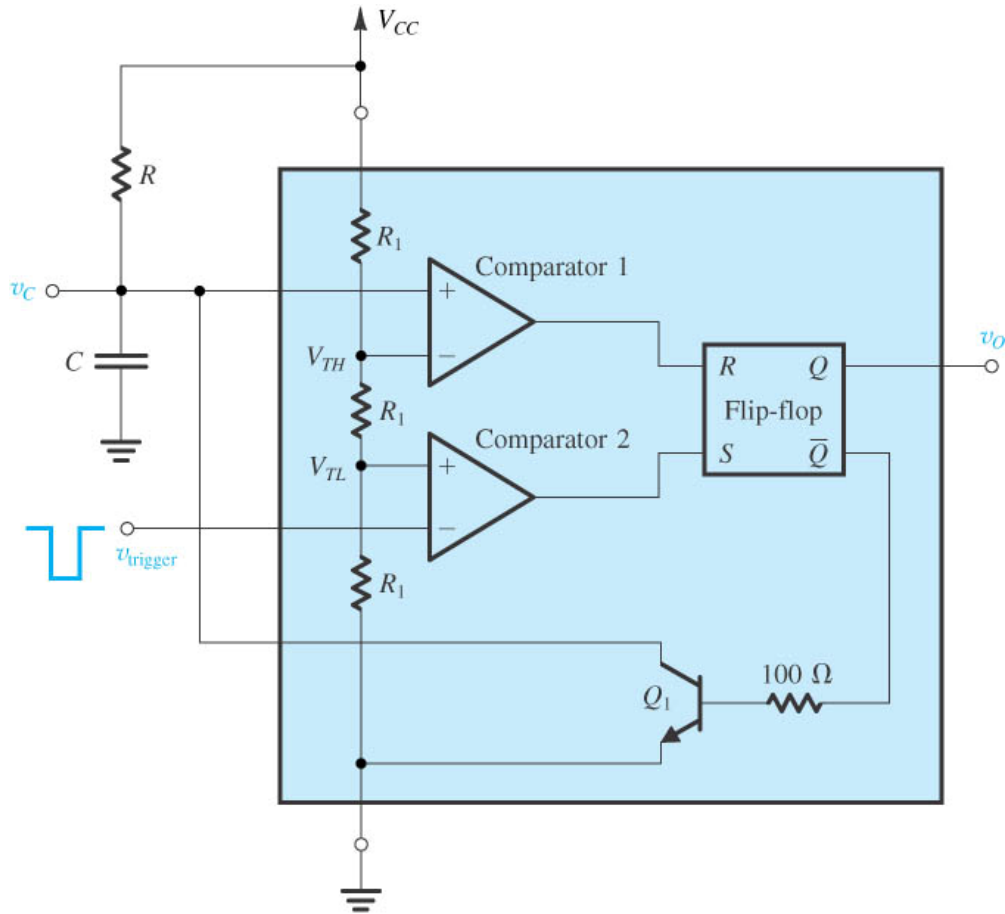
The circuit consists of two comparators, which drive an RS flip-flop, an output buffer, and a transistor that discharges an external timing capacitor. Comparator 1 is called the threshold comparator which converts its input with an internal voltage reference set at  $2/3 V_{CC}$ . Comparator 2, called the trigger comparator, compares the input trigger voltage to an internal voltage reference set at  $1/3 V_{CC}$ .



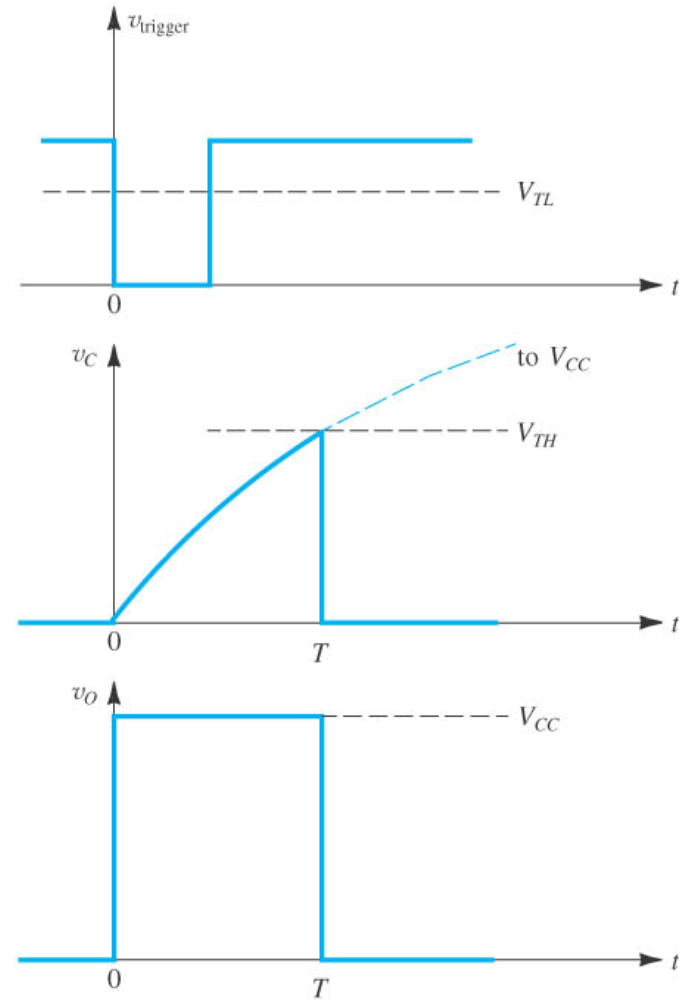
# Implementing a Monostable Multivibrator Using the 555 IC

$$v_C = V_{CC}(1 - e^{-t/RC}); v_C = V_{TH} = \frac{2}{3}V_{CC} \text{ at } t = T$$

$$T = CR \ln 3 = 1.1CR$$



(a)



(b)

# Operation of Monostable Multivibrator

- It called also one shot, operates by charging a timing capacitor with a current set by external resistance.
- When the one shot is triggered, the charging network cycles only once during the timing interval. The total timing interval includes the recovery time needed for the capacitor to charge up to the threshold level.
- When  $V_{cc}$  high is applied to the trigger input, the trigger comparator output is low, the flip flop output is high, the transistor is on, the timing capacitor is discharged to ground potential. The output of the 555 circuit is low.
- When negative voltage is applied to the trigger input, output of trigger comparator goes high. When trigger pulse drops below  $1/3 V_{cc}$  output of flip flop goes low, output of 555 circuit goes high and the transistor turns off

**Design problem:** Design the 555 IC as a monostable multivibrator with a 100  $\mu$ s output pulse. Let  $C = 15$  nF.

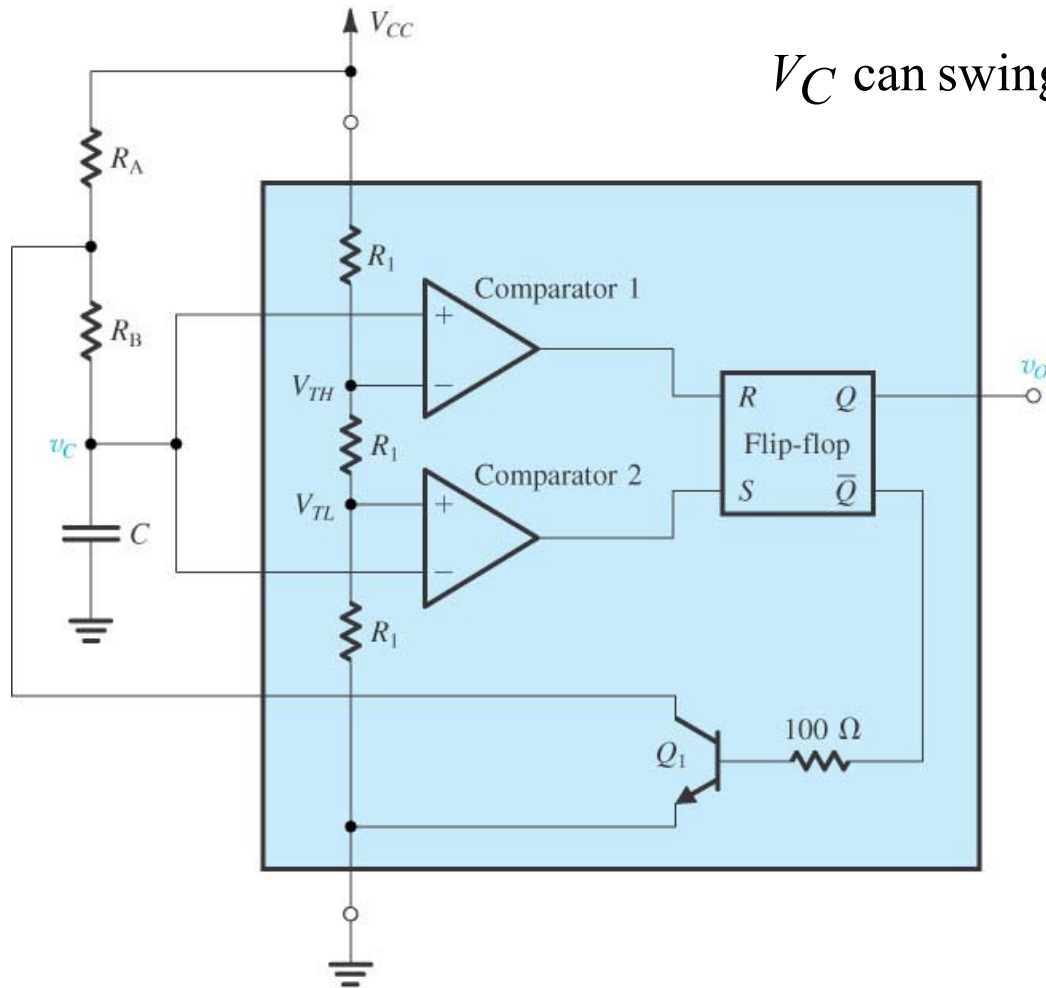
The pulse width is a function of only the external resistor and capacitance values. A wide range of pulse widths can be obtained by changing these component values.

The 555 timer is popular for low frequency applications, but it cannot be used when smaller rise and fall times are required.

The 555 timer is designed to operate with a power-supply voltage ranging from 5 V to 18 V.

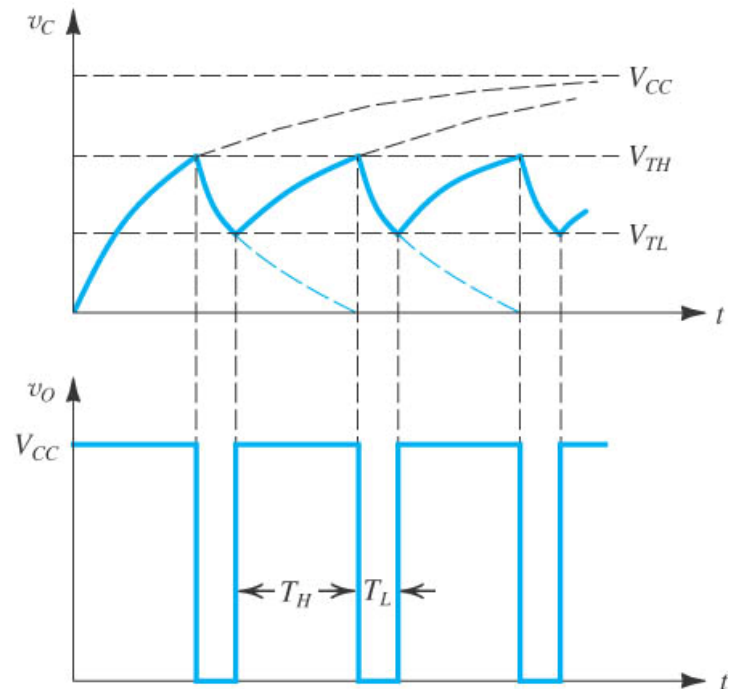
$$R = \frac{T}{1.1C} = \frac{100 \times 10^{-6}}{(1.1)(15 \times 10^{-9})} = 6.06 \text{ k}\Omega$$

# An Astable Multivibrator Using the 555 IC



(a)

$V_C$  can swing between  $V_{CC} / 3$  and  $2V_{CC} / 3$



(b)

**Design problem:** Design the 555 IC as an astable multivibrator for a specific frequency and duty cycle. Assume the frequency 50 kHz and the duty cycle as 75 %. Let  $C = 1 \text{ nF}$ .

$$f = \frac{1}{0.69(R_A + 2R_B)C}$$

$$R_A + 2R_B = \frac{1}{(0.69)fC} = 28.9 \text{ k}\Omega$$

$$\text{Duty Cycle} = 0.75 = \frac{R_A + R_B}{R_A + 2R_B}$$

$$R_A = 2R_B$$

$$R_A = 14.5 \text{ k}\Omega \text{ and } R_B = 7.23 \text{ k}\Omega$$

# Applications

When the 555 is connected in the monostable mode, an external signal applied to the control voltage terminal will change time of the timing capacitor and the pulse width. If the one shot is triggered with a continuous pulse train, the output pulse width will be modulated by the external signal. This circuit is called a **pulse width modulator**.

A **pulse position modulator** can also be developed using the astable mode. A modulating signal applied to the control voltage terminal will vary the pulse position.

A **linear ramp generator** can also be constructed, using the 555 monostable mode, if  $R$  is replaced by a constant current source

## **Design Task**

Utilize the astable-multivibrator circuit to design an inexpensive function generator that provides square, triangle, and sine wave output at frequencies up to few MHz



**Design task:** A light sensor has a  $2\text{-k}\Omega$  output impedance and generates a triangle waveform as shown below when the light is detected. Design a circuit that produces a rectangular output pulse of duration  $300\text{ }\mu\text{s}$  and magnitude of at least  $4\text{ V}$  when the triangle waveform is applied.

