Sedra/Smith Microelectronic Circuits

Implementing a Monostable Multivibrator Using the 555 IC

Figure 12.28(a) shows a monostable multivibrator implemented using the 555 IC together with an external resistor R and an external capacitor C. In the stable state the flip-flop will be in the reset state, and thus its $\overline{Q}$ output will be high, turning on transistor Q_1. Transistor Q_1 will be saturated, and thus v_C will be close to 0 V, resulting in a low level at the output of comparator 1. The voltage at the trigger input terminal, labeled $v_{trigger}$, is kept high (greater than V_{TL}), and thus the output of comparator 2 also will be low. Finally, note that since the flip-flop is in the reset state, Q will be low and thus v_O will be close to 0 V.

To trigger the monostable multivibrator, a negative input pulse is applied to the trigger input terminal. As $v_{trigger}$ goes below V_{TL}, the output of comparator 2 goes to the high level, thus setting the flip-flop. Output Q of the flip-flop goes high, and thus v_O goes high, and output $\overline{Q}$ goes low, turning off transistor Q_1. Capacitor C now begins to charge up through resistor R, and its voltage v_C rises exponentially toward V_{CC}, as shown in Fig. 12.28(b). The monostable multivibrator is now in its quasi-stable state. This state prevails until v_C reaches, and begins to exceed, the threshold of comparator 1, V_{TH}, at which time the output of comparator 1 goes high, resetting the flip-flop. Output $\overline{Q}$ of the flip-flop now goes high and turns on transistor Q_1. In turn, transistor Q_1 rapidly discharges capacitor C, causing v_C to go to 0 V. Also, when the flip-flop is reset its Q output goes low, and thus v_O goes back to 0 V. The monostable multivibrator is now back in its stable state and is ready to receive a new triggering pulse.

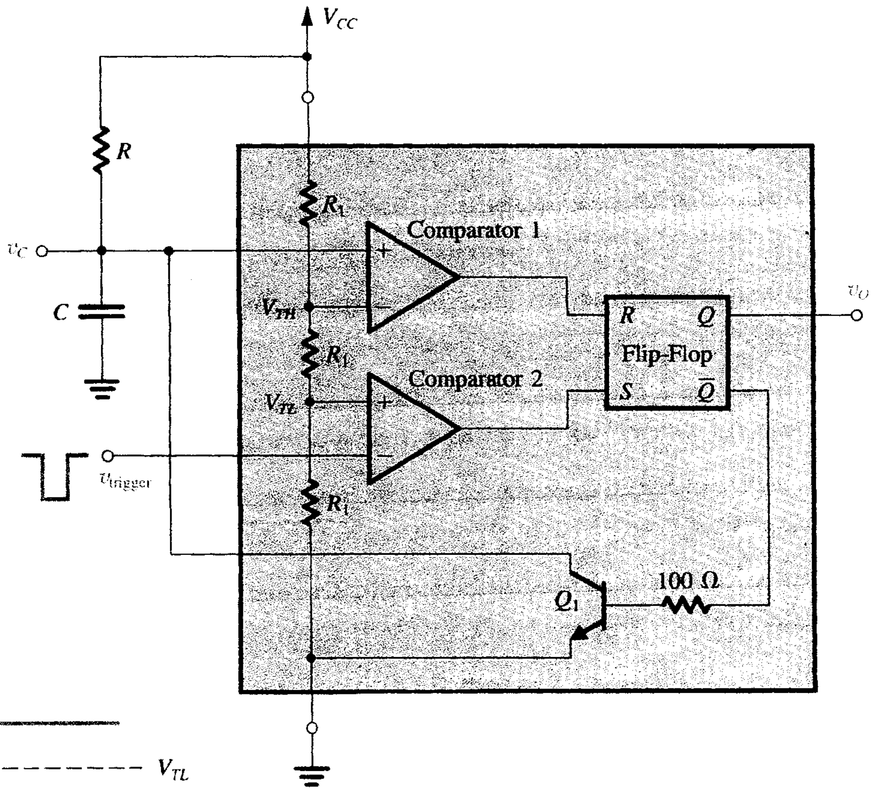
From the above description we see that the monostable multivibrator produces an output pulse v_O as indicated in Fig. 12.28(b). The width of the pulse, T, is the time interval that the monostable multivibrator spends in the quasi-stable state; it can be determined by reference to the waveforms in Fig. 12.28(b) as follows: Denoting the instant at which the trigger pulse is applied as $t = 0$, the exponential waveform of v_C can be expressed as

$$v_C = V_{CC}(1 - e^{-t/CR}) \tag{12.38}$$

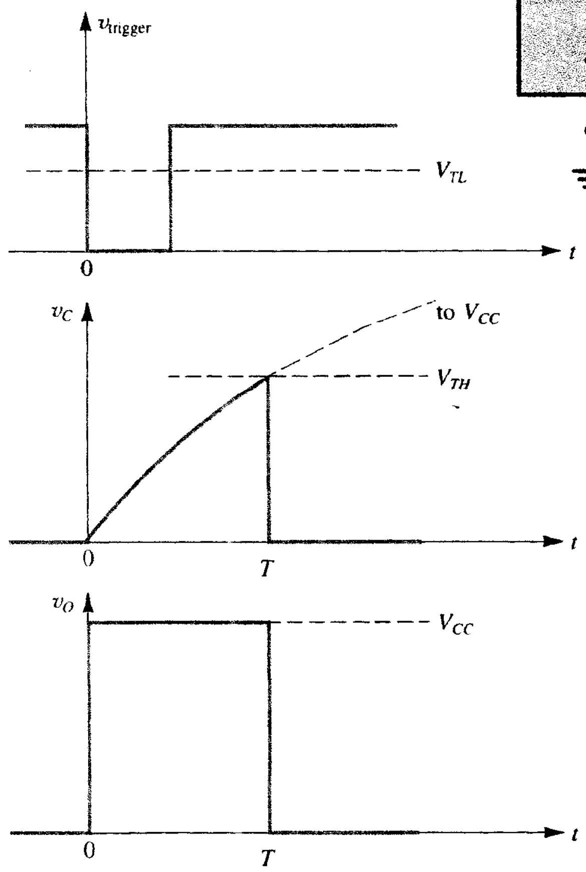
Substituting $v_C = V_{TH} = \frac{2}{3}V_{CC}$ at $t = T$ gives

$$T = CR \ln 3 \simeq 1.1CR \tag{12.39}$$

Thus the pulse width is determined by the external components C and R, which can be selected to have values as precise as desired.



(a)



(b)

Fig. 12.28 **(a)** The 555 timer connected to implement a monostable multivibrator. **(b)** Waveforms of the circuit in (a).

An Astable Multivibrator Using the 555 IC

Figure 12.29(a) shows the circuit of an astable multivibrator employing a 555 IC, two external resistors, R_A and R_B, and an external capacitor C. To see how the circuit operates refer to the waveforms depicted in Fig. 12.29(b). Assume that initially C is discharged and the flip-flop is set. Thus v_O is high and Q_1 is off. Capacitor C will charge up through the series combination of R_A and R_B, and the voltage across it, v_C, will rise exponentially toward V_{CC}. As v_C crosses the level equal to V_{TL}, the output of comparator 2 goes low. This, however, has no effect on the circuit operation, and the flip-flop remains set. Indeed, this state continues until v_C reaches and begins to exceed the threshold of comparator 1, V_{TH}. At this instant of time, the output of comparator 1 goes high and resets the flip-flop. Thus v_O goes low, $\overline{Q}$ goes high, and transistor Q_1 is turned on. The saturated transistor Q_1 causes a voltage of approximately zero volts to appear at the common node of R_A and R_B. Thus C begins to discharge through R_B and the collector of Q_1. The voltage v_C decreases exponentially with a time constant CR_B toward 0 V. When v_C reaches the threshold of comparator 2, V_{TL}, the output of comparator 2, goes high and sets the flip-flop. The output v_O then goes high, and $\overline{Q}$ goes low, turning off Q_1. Capacitor C begins to charge through the series equivalent of R_A and R_B, and its voltage rises exponentially toward V_{CC} with a time constant $C(R_A + R_B)$. This rise continues until v_C reaches V_{TH}, at which time the output of comparator 1 goes high, resetting the flip-flop, and the cycle continues.

From the above description we see that the circuit of Fig. 12.29(a) oscillates and produces a square waveform at the output. The frequency of oscillation can be determined as follows. Reference to Fig. 12.29(b) indicates that the output will be high during the interval T_H, in which v_C rises from V_{TL} to V_{TH}. The exponential rise of v_C can be described by

$$v_C = V_{CC} - (V_{CC} - V_{TL})e^{-t/C(R_A+R_B)} \tag{12.40}$$

where $t = 0$ is the instant at which the interval T_H begins. Substituting $v_C = V_{TH} = \frac{2}{3}V_{CC}$ at $t = T_H$ and $V_{TL} = \frac{1}{3}V_{CC}$ results in

$$T_H = C(R_A + R_B)\ln 2 \simeq 0.69\, C(R_A + R_B) \tag{12.41}$$

We also note from Fig. 12.29(b) that v_O will be low during the interval T_L, in which v_C falls from V_{TH} to V_{TL}. The exponential fall of v_C can be described by

$$v_C = V_{TH}\, e^{-t/CR_B} \tag{12.42}$$

where we have taken $t = 0$ as the beginning of the interval T_L. Substituting $v_C = V_{TL} = \frac{1}{3}V_{CC}$ at $t = T_L$ and $V_{TH} = \frac{2}{3}V_{CC}$ results in

$$T_L = CR_B \ln 2 \simeq 0.69\, CR_B \tag{12.43}$$

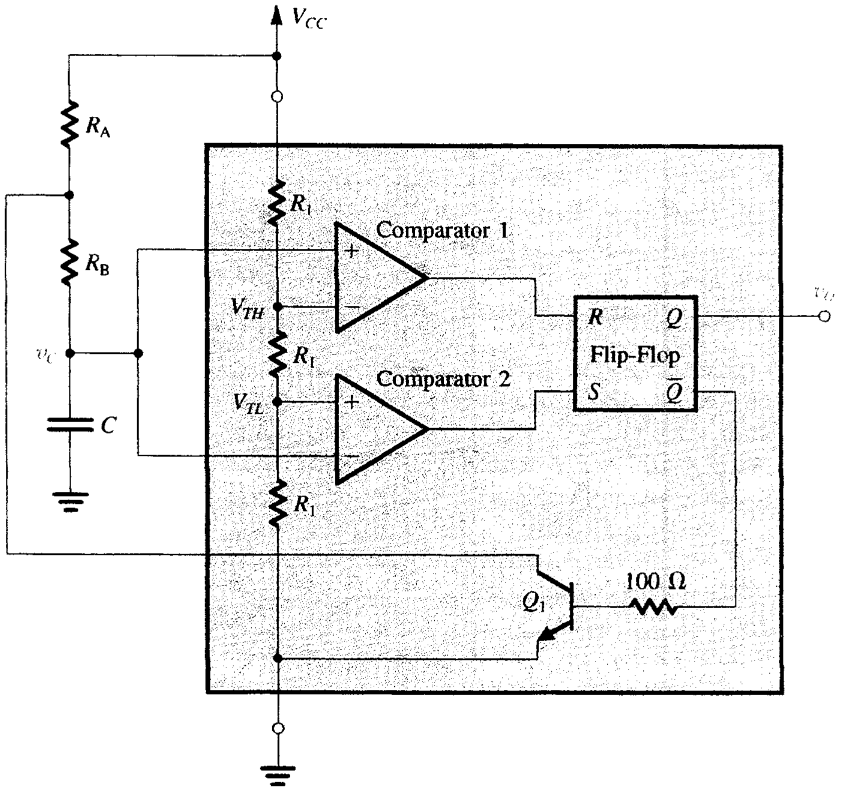
Equations (12.41) and (12.43) can be combined to obtain the period T of the output square wave as

$$T = T_H + T_L = 0.69\, C(R_A + 2R_B) \tag{12.44}$$

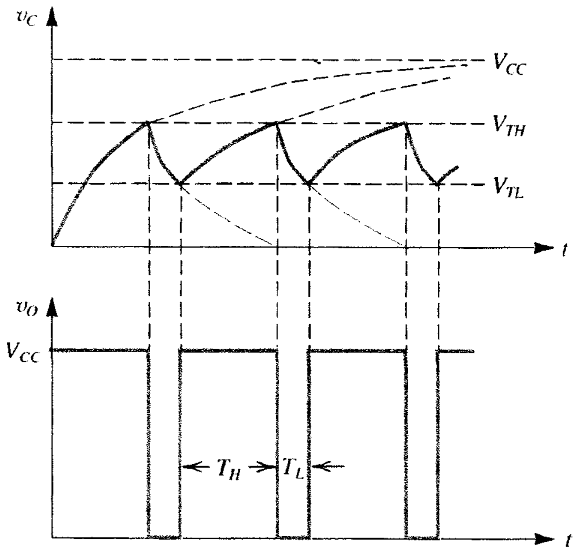
Also, the **duty cycle** of the output square wave can be found from Eqs. (12.41) and (12.43):

$$\text{Duty cycle} \equiv \frac{T_H}{T_H + T_L} = \frac{R_A + R_B}{R_A + 2R_B} \tag{12.45}$$

Note that the duty cycle will always be greater than 0.5 (50%); it approaches 0.5 if R_A is selected much smaller than R_B.



(a)



(b)

Fig. 12.29 **(a)** The 555 timer connected to implement an astable multivibrator.
(b) Waveforms of the circuit in (a).