MONOSTABLE MULTIVIBRATORS

SUMMARY

- A monostable multivibrator has one stable state and one quasi-stable state.
- The main application of a monostable multivibrator is as a gate that generates a pulsed output.
- The gate width of collector-coupled monostable multivibrator is liable to change with temperature variations.
- A monostable multivibrator can be used as a voltage-to-time converter.
- In a collector-coupled monostable multivibrator, to ensure that the gate width remains constant, the ON device is required to be driven into saturation, in the quasi-stable state.
- The emitter-coupled monostable multivibrator may operate as a free-running multivibrator if $V > V_{(max)}$.
- In an emitter-coupled monostable multivibrator, even if the ON device is held in the active region; in the quasi-stable state, because of a substantial emitter-resistance which stabilizes the current, the gate width can be maintained stable.

MULTIPLE CHOICE QUESTIONS

1. A monostable multivibrator is also known by the name:
   a) Flip-flop
   b) Free-running multivibrator
   c) One-shot multivibrator
   d) Schmitt trigger
2. A monostable multivibrator can be used as a:
   a) Voltage-to-time converter
   b) Clock
   c) Squaring circuit
   d) Flip-flop
3. The gate width of a collector-coupled monostable multivibrator in which the ON device, in the quasi-stable state, is in saturation is given by the relation:
   a) $T = 0.69\ RC$
   b) $T = 69\ RC$
   c) $T = \sqrt{0.69RC}$
   d) $T = = \sqrt{69}RC$
4. The multivibrator that can be used as a gating circuit is:
   a) Bistable multivibrator
   b) Schmitt trigger
   c) Monostable multivibrator
   d) Astable multivibrator
5. The gate width of an emitter-coupled multivibrator is:
   a) Independent of temperature variation
   b) Varies with temperature
   c) Varies with variation of device parameters
   d) None of the above

6. The expression for the gate width of collector-coupled monostable multivibrator, considering I_{CO} is given by:

a) $T = 0.69RC$
b) $T = \sqrt{0.69RC}$
c) $T = 69RC$
d) $T = \tau \ln 2 - \tau \ln [(1 + \varphi)/(1 + \varphi/2)]$

SHORT ANSWER QUESTIONS

1. The main application of a monostable multivibrator is as a gating circuit, explain.
2. Explain, how you can use a monostable multivibrator as a voltage-to-time converter.
3. The expression for the gate width of a collector-coupled monostable multivibrator is given as $T = \tau \ln (V_{CC} - V_\sigma + I_1 R_C)/(V_{CC} - V_\gamma)$ where I_1 is the current in Q_1, when ON in the quasi-stable state. If the ON device is driven into saturation, show that $T = 0.69\tau$.
4. What is the main advantage of an emitter-coupled monostable multivibrator over collector-coupled monostable multivibrator?
5. Draw the circuit of an emitter-coupled monostable multivibrator and explain its operation.

LONG ANSWER QUESTIONS

1. Draw the circuit of a collector-coupled monostable multivibrator and explain its operation. Obtain the expression for its gate width and show that the gate width can be stable if the ON device is driven into saturation, in the quasi-stable state. Draw the waveforms.
2. Draw the circuit of a voltage-to-time converter and obtain the expression for the time period.
3. With the help of a circuit diagram and waveforms, explain the working of an emitter-coupled monostable multivibrator. Derive the expression for its gate width.

SOLVED PROBLEMS

Example 8.1: Calculate the gate width for the monostable multivibrator given that $R = 100$ kΩ, $V_{CC} = 10$ V, $C = 0.01$ μF;
Solution:

$$\tau = RC = 100 \times 10^3 \times 0.01 \times 10^{-6} = 1 \text{ ms}$$
$$T = 0.69 \times 100 \times 10^3 \times 0.01 \times 10^{-6} = 0.69 \text{ ms.}$$

Example 8.6: For the monostable multivibrator shown in Fig. 8.1, $R_1 = R_2 = R = 20$ kΩ, $C = 0.01$ μF, $R_C = 2$kΩ, $V_{CC} = 12$ V, $V_{BB} = -12$ V. Find the time period T.

Solution:

Time period $T = 0.69RC = 0.69 \times 20 \times 10^3 \times 0.01 \times 10^{-6} = 138$ μs

Example 8.2: Consider the circuit shown in Fig. 8.8(a), which uses an ***n–p–n*** silicon transistors with the following specifications: V_{CC} = 10 V, V_{BB} = 10 V, R_C = 1 kΩ, R_1 = 10 kΩ = R, R_2 = 100 kΩ, $h_{FE(min)}$ = 30, r_{bb} = 0.2 kΩ, $V_{CE(sat)}$ = 0.3 V, $V_{BE(sat)} = V_\sigma$ = 0.7 V. Calculate all the current and voltages and then plot the waveforms.

Solution: (i) In the stable state ($t < 0$)

The assumption made is Q_2 is ON and in saturation and Q_1 is OFF. To verify that Q_2 is ON and in saturation, I_{C2} and I_{B2} of Q_2 are to be calculated. Further check whether $I_{B2} >> I_{B2}$ (min) or not. If $I_{B2} >> I_{B2}$ (min), then Q_2 is really in saturation. Consider the circuit shown in Fig. 8.8(b).

(a) To verify if Q_2 is ON and in saturation:

$$I_{C2} = I_2 - I_3 \qquad I_2 = \frac{V_{CC} - V_{CE(\text{sat})}}{R_C} = \frac{10 - 0.3}{1\text{ k}\Omega} = 9.7\text{ mA}$$

$$I_3 = \frac{V_{CE(\text{sat})} - (-V_{BB})}{R_1 + R_2} = \frac{10.3}{110\text{ k}\Omega} = 0.0934\text{ mA}$$

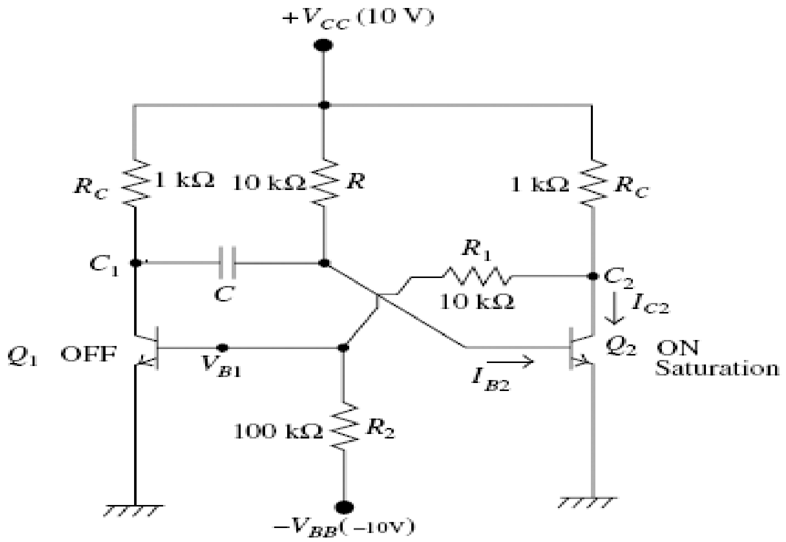

FIGURE 8.8(a) Practical collector-coupled monostable multivibrator

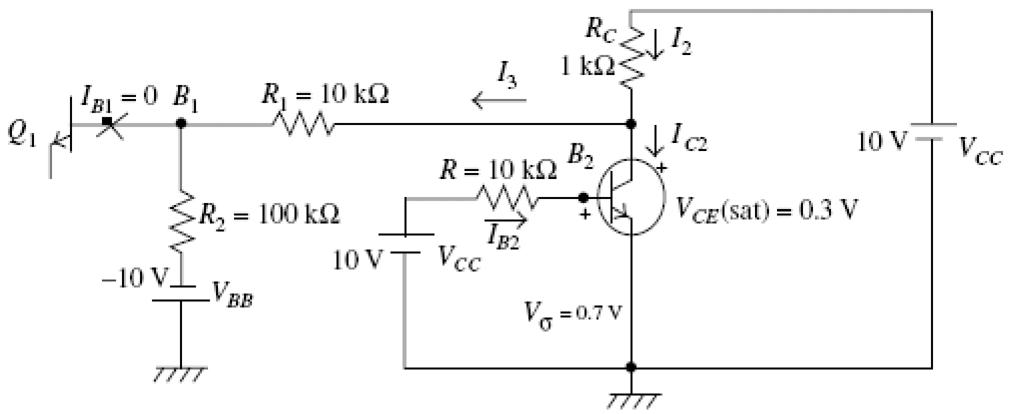

FIGURE 8.8(b) In the stable state, Q_1 is OFF and Q_2 is ON

$\therefore I_{C2} = I_2 - I_3 = 9.7\text{ mA} - 0.0934\text{ mA} = 9.61\text{ mA}$

$$I_{B2} = \frac{V_{CC} - V_\sigma}{R} = \frac{10 - 0.7}{10\text{ k}\Omega} = 0.93\text{ mA} \qquad I_{B2\,(\min)} = \frac{I_{C2}}{h_{FE\,(\min)}} = \frac{9.61\text{ mA}}{30} = 0.32\text{ mA}$$

For Q_2 to be in saturation, I_{B2} should be at least 1.5 I_{B2} (min). Hence, I_{B2} should be selected to keep Q_2 in saturation as

$I_{B2} = 1.5 \times 0.32\text{ mA} = 0.48\text{ mA}$.

As I_{B2}(0.93 mA) >> 1.5$I_{B2(\min)}$(0.48 mA), as per the assumption made Q_2 is really in saturation. Hence,

$$V_{C2} = 0.3\text{ V, and } V_{B2} = 0.7\text{ V.}$$

b) To verify that Q_1 is OFF:

To verify whether Q_1 is in the OFF state or not, $V_{B1} = V_{BE1}$ is calculated and seen if it reverse-biases the base–emitter diode. The voltage V_{B1} is due to two sources—the V_{BB} source and the $V_{CE(\text{sat})}$ source, as shown in Fig. 8.8(c). Use the superposition theorem to calculate V_{B1}, considering one source at a time. Considering the $V_{CE(\text{sat})}$ source and shorting the V_{BB} source, the resultant circuit is as shown in Fig. 8.8(d).

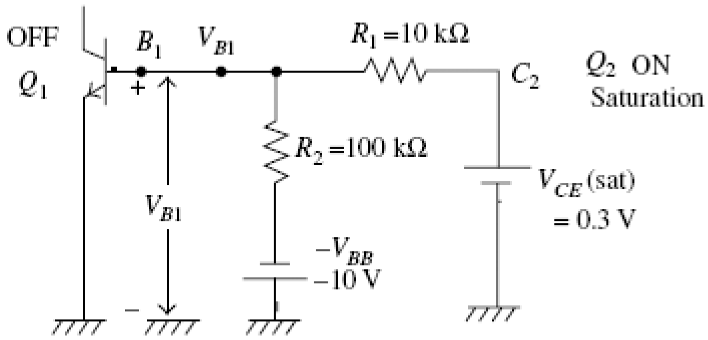

FIGURE 8.8(c) The circuit for calculating V_{B1}

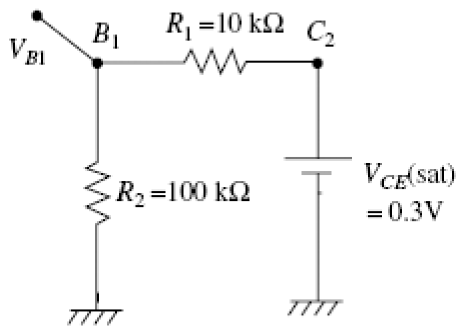

FIGURE 8.8(d) The circuit to calculate V_{B1} due to $V_{CE(\text{sat})}$ source

$$V_{B1}(V_{BB} = 0) = V_{CE(\text{sat})} \times \frac{R_2}{R_1 + R_2} = 0.3 \times \frac{100}{100 + 10} = \frac{3}{11} = 0.27\text{ V}$$

Now shorting the $V_{CE(\text{sat})}$ source, the resultant circuit is as shown in Fig. 8.8(e).

$$V_{B1}(V_{CE(sat)} = 0) = -10 \times \frac{10}{110} = \frac{-10}{11} = -0.91\ \text{V}$$

Therefore, the net voltage V_{B1} at B_1 due to the two sources $V_{CE(sat)}$ and $-V_{BB}$ is

$V_{B1} = 0.27 - 0.91 = -0.64$ V.

This explains that the base of Q_1 is negative with respect to the emitter by 0.64 V. Hence, the base–emitter diode is reverse-biased. Therefore, Q_1 is OFF, as assumed. Hence, $V_{C1} = V_{CC} =$ 10 V. The voltage across the capacitor terminals is

$V_A = V_{C1} - V_{B2} = V_{CC} - V\sigma = 10\ \text{V} - 0.7\ \text{V} = 9.3\ \text{V}$

In the stable state, the voltages are $V_{B1} = -0.64$ V, $V_{C1} = 10$ V, $V_{B2} = 0.7$ V, $V_{C2} = 0.3$ V, $V_A =$ 9.3 V.

ii) In the quasi-stable state ($t = 0+$)

In the quasi-stable state, Q_2 is driven into the OFF state, by the application of a trigger. Consequently, Q_1 goes into the ON state and into saturation as shown in Fig. 8.8(f).

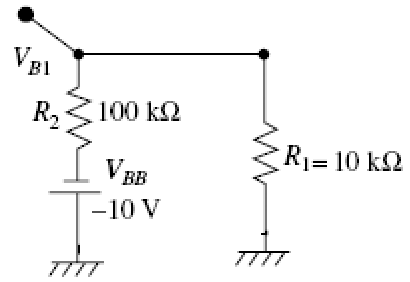

FIGURE 8.8(e) Circuit to calculate V_{B1} due to $-V_{BB}$ source

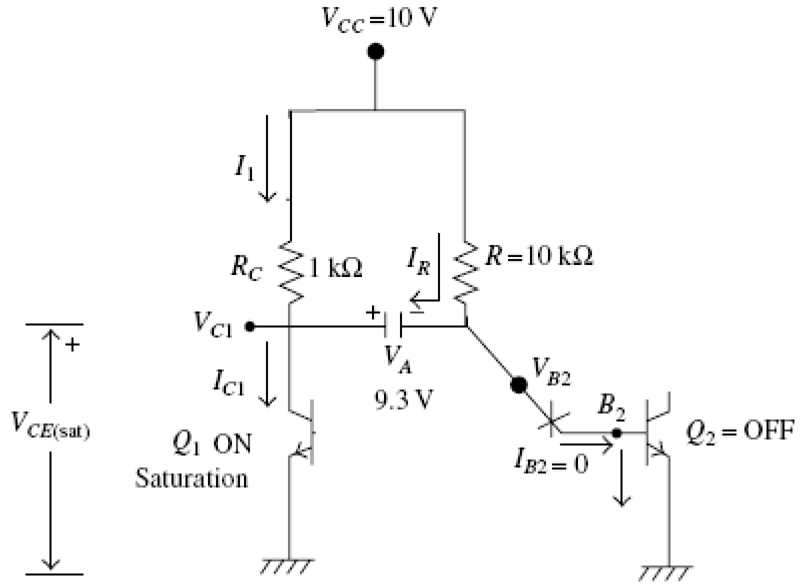

FIGURE 8.8(f) In the quasi-stable state, Q_1 is ON and Q_2 is OFF

a) To verify if $\boldsymbol{Q_1}$ is ON and in saturation or not

To verify whether $\boldsymbol{Q_1}$ is really in saturation or not, calculate $\boldsymbol{I_{C1}}$.

$$I_{C1} = I_1 + I_R \qquad I_1 = \frac{V_{CC} - V_{CE(\text{sat})}}{R_C} = \frac{10 - 0.3}{1\text{ k}\Omega} = 9.7\text{ mA}$$

To calculate $\boldsymbol{I_R}$ the KVL equation of the loop consisting of $\boldsymbol{R_C}$, $\boldsymbol{C}$ and $\boldsymbol{R}$ is,

$$\boldsymbol{I_R R} = \boldsymbol{I_1 R_C} + \boldsymbol{V_A} = 9.7\text{ V} + 9.3\text{ V} = 19\text{ V} \qquad I_R = \frac{19\text{ V}}{10\text{ k}\Omega} = 1.9\text{ mA}$$

Therefore,

$$\boldsymbol{I_{C1}} = \boldsymbol{I_1} + \boldsymbol{I_R} = 9.7\text{ mA} + 1.9\text{ mA} = 11.6\text{ mA}$$

$$I_{B1(\text{min})} = \frac{I_{C1}}{h_{FE\text{ min}}} = \frac{11.6\text{ mA}}{30} = 0.39\text{ mA}$$

To calculate $\boldsymbol{I_{B1}}$, consider Fig. 8.8(g).

$\boldsymbol{I_{B1}} = \boldsymbol{I_3} - \boldsymbol{I_4}$

$$I_3 = \frac{V_{CC} - V_\sigma}{R_C + R_1} = \frac{10 - 0.7}{1 + 10} = \frac{9.3\text{ V}}{11\text{ k}\Omega} = 0.84\text{ mA}$$

$$I_4 = \frac{V_\sigma - (-V_{BB})}{R_2} = \frac{0.7 + 10}{100\text{ k}\Omega} = \frac{10.7\text{ V}}{100\text{ k}\Omega} = 0.11\text{ mA}$$

$\boldsymbol{I_{B1}} = 0.84 - 0.11 = 0.73\text{ mA}$

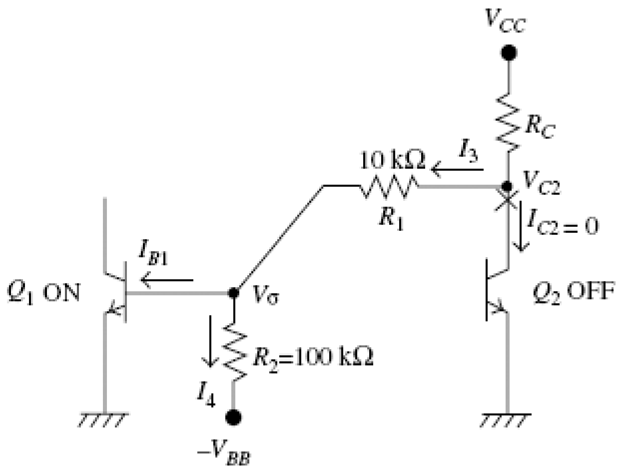

FIGURE 8.8(g) The circuit that is used to calculate $\boldsymbol{I_{B1}}$

As already calculated, $\boldsymbol{I_{B1(\text{min})}} = 0.39$ mA. Thus, $\boldsymbol{I_{B1}} >> \boldsymbol{I_{B1(\text{min})}}$.

Hence, $\boldsymbol{Q_1}$ is in saturation.

$$\therefore V_{C1} = 0.3 \text{ V}, V_{B1} = 0.7 \text{ V},$$

$V_{C2} = V_{CC} - I_3R_C = 10 - (0.84)(1) = 9.16$ V (But for the current, I_3, V_{C2} should have been 10 V)

$V_{B2} = V_{CC} - I_RR = 10 - (1.9)(10) = -9$ V

In the quasi-stable state, except V_{B2}—which changes exponentially as a function of time—all other voltages remain unaltered. At $t = T$, when $V_{B2} = V_\gamma$, the quasi-stable state ends and the multivibrator returns to its initial stable condition. The voltages at the beginning of the quasi-stable state are $V_{C1} = 0.3$ V, $V_{B1} = 0.7$ V, $V_{C2} = 9.16$ V, $V_{B2} = -9$ V initially and varies exponentially.

iii) At the end of the quasi-stable state (at $t = T+$)

At the end of the quasi-stable state Q_1 goes OFF and Q_2 goes ON and into saturation, resulting in overshoots at the base of Q_2 and at the collector of Q_1. The overshoots are calculated using Fig. 8.8(h).

Neglecting the current I_R when compared to I'_{B2} the circuit reduces to Fig. 8.8(i).

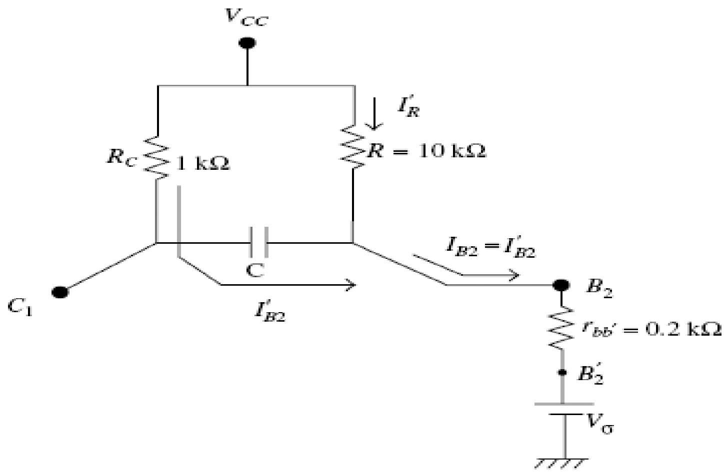

FIGURE 8.8(h) The circuit that is used to calculate I_{B1}

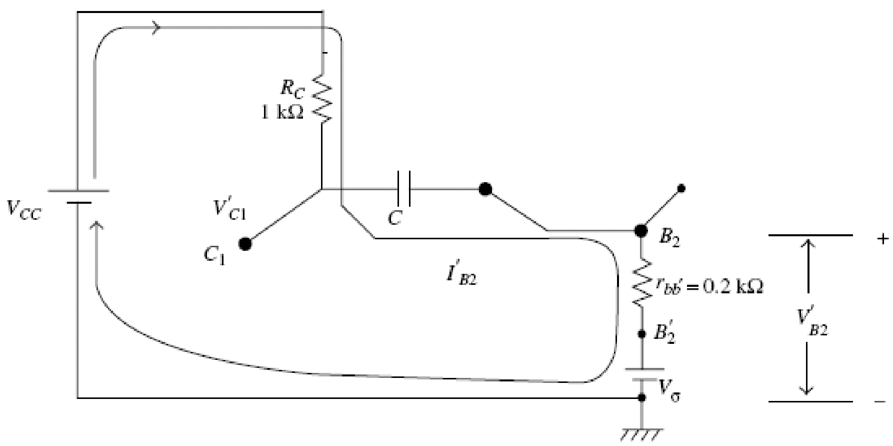

FIGURE 8.8(i) The simplified circuit of Fig. 8.8(h)

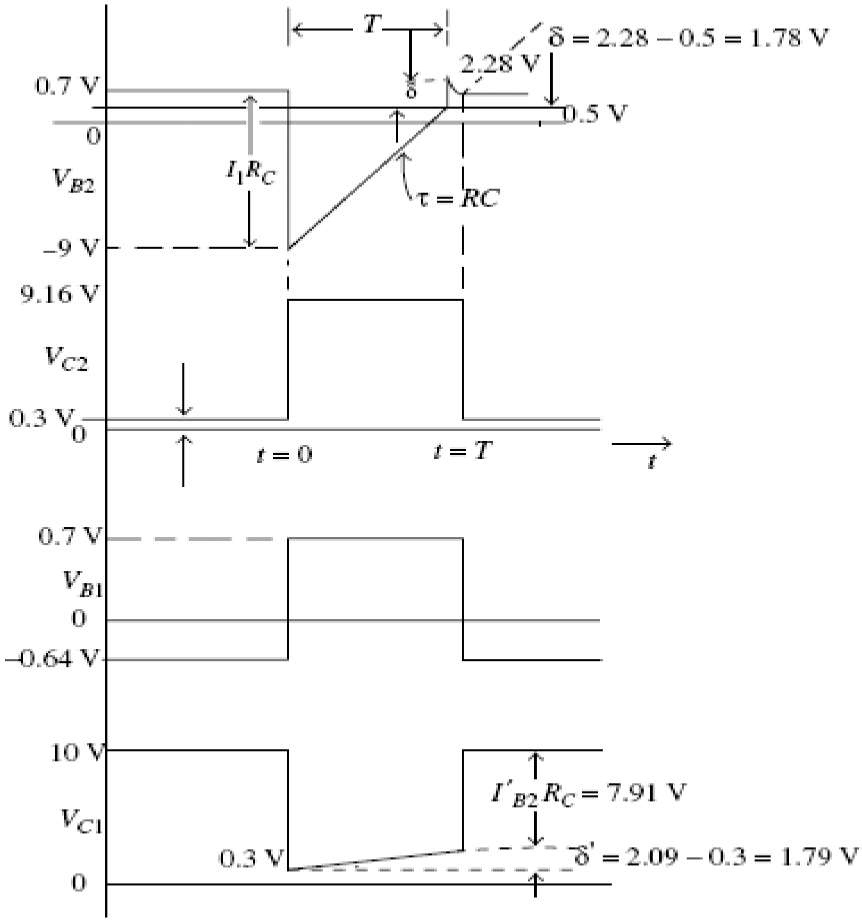

FIGURE 8.8(j) Waveforms of the collector-coupled monostable

Using Eq. (8.34):

$$I'_{B2} = \frac{V_{CC} - V_{CE(\text{sat})} - V_\sigma + V_\gamma}{r_{bb'} + R_C}$$

$$= \frac{10 - 0.3 - 0.7 + 0.5}{0.2 + 1} = \frac{9.5\,\text{V}}{1.2\,\text{k}\Omega}$$

$I'_{B2} = 7.91$ mA

$V'_{C1} = V_{CC} - I'_{B2}R_C = 10 - (7.91)(1)$

$V'_{C1} = 2.09$ V

$V'_{B2} = I'_{B2}r_{bb'} + V_\sigma$

$= (7.91)(0.2) + 0.7 = 1.58 + 0.7$

$V'_{B2} = 2.28$ V

At $t = T+$, the voltages are $V_{C2} = 0.3$ V, $V_{B2} = 2.28$ V, $V_{C1} = 10$ V, $V_{B1} = -0.64$ V. The waveforms are plotted as shown in Fig. 8.8(j).

Example 8.3: Design a collector-coupled monostable circuit of Fig. 8.1 to generate a pulse of width 100 μs. Silicon devices with $h_{FE(\text{min})} = 50$ are used. ON device is in saturation.

Given that:

$V_{CC} = 12$ V, $V_{CE(\text{sat})} = 0.2$ V, $V_{BE(\text{sat})} = 0.7$ V, $I_{B(\text{sat})} = 2\, I_{B(\text{min})}$, $V_{BB} = 12$ V, $I_{C(\text{sat})} = 2$ mA, $T = 100\ \mu$s.

Solution:

1. Let Q_2 be ON and Q_1 be OFF.

$$R_{C2} = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C2(\text{sat})}} = \frac{12 - 0.2}{2\,\text{mA}} = \frac{11.8}{2\,\text{mA}} = 5.9\,\text{k}\Omega \approx 6\,\text{k}\Omega$$

$$I_{B2\,(\text{min})} = \frac{I_{C2(\text{sat})}}{h_{FE\,(\text{min})}} = \frac{2\,\text{mA}}{50} = 40\,\mu\text{A}$$

$I_{B2(\text{sat})} = 2 \times I_{B2}\,(\text{min}) = 2 \times 40 = 80\ \mu$A

$$R = \frac{V_{CC} - V_\sigma}{I_{B2(\text{sat})}} = \frac{12 - 0.7}{80\,\mu\text{A}} = \frac{11.3}{80 \times 10^{-6}} = \frac{1130}{8} \times 10^3 = 141\,\text{k}\Omega$$

$h_{FE}R_C = 50 \times 6 = 300$ kΩ

For ON device to be in saturation,

$R \leq h_{FE}R_C$

Hence, the condition is verified.

2. When Q_1 is ON, let I_2 be the current in R_2.

$$I_2 \approx \frac{1}{10} I_{C(\text{sat})} = 0.2\,\text{mA} \qquad R_2 = \frac{V_\sigma + V_{BB}}{I_2} = \frac{12.7}{0.2} = 63.5\,\text{k}\Omega$$

Let I_1 be the current in $R_C + R_1$.

$I_1 = I_{B1} + I_2 = 0.08 + 0.2 = 0.28$ mA

$$R_C + R_1 = \frac{V_{CC} - V_\sigma}{I_1} = \frac{12 - 0.7}{0.28\,\text{mA}} = 40\,\text{k}\Omega$$

$R_1 = (R_C + R_1) - R_C = 40 - 6 = 34$ kΩ

$T = 0.69RC \rightarrow 100 \times 10^{-6}\ s = 0.69 \times 141 \times 10^3 \times C$

$$C = \frac{100 \times 10^{-6}}{0.69 \times 141 \times 10^3} = \frac{100}{7 \times 14} \times 10^{-9} \approx 1\,\text{nF}$$

Example 8.5: Design the monostable multivibrator shown in Fig. 8.11(a) having V_{CC} = 18 V and V = 6 V, h_{FE} = 50, $I_{C(\text{sat})}$ = 5 mA.

Solution:

For V to be 6 V, choose R_1 = 200 kΩ, R_2 = 100 kΩ, (to avoid loading the dc source) and C_b = 10 μF (bypass condenser). Given that $I_{C(\text{sat})}$ = 5 mA, assume Q_1 is OFF and Q_2 is ON and in saturation, in the stable state.

Let

$$V_{EN} = V_{EN2} = \frac{V_{CC}}{2} = 9\,\text{V}$$

Therefore,

$V_{BE1} = V - V_{EN2} = 6 - 9 = -3$ V

Hence, Q_1 is OFF.

$$R_E = \frac{V_{EN2}}{I_E} = \frac{9\,\text{V}}{5\,\text{mA}} = 1.8\,\text{k}\Omega$$

Choose R_E = 2kΩ

$$R_{C1} = R_{C2} = \frac{V_{CC} - V_{CE}(\text{sat}) - V_{EN2}}{I_{C2}} = \frac{18 - 0.2 - 9}{5\,\text{mA}} = \frac{8.8\,\text{V}}{5\,\text{mA}} = 1.75\,\text{k}\Omega$$

$$I_{B2(\text{min})} = \frac{I_{C2}}{h_{FE(\text{min})}} = 0.1\,\text{mA}$$

Let

$I_{B2} = 1.5 \times I_{B2(\text{min})} = 0.15$ mA

$$R = \frac{V_{CC} - V_{\sigma} - V_{EN2}}{I_{B2}} = \frac{18 - 0.7 - 9}{0.15\,\text{mA}} = \frac{8.3\,\text{V}}{0.15\,\text{mA}} \approx 55\,\text{k}\Omega$$

Choose $R \approx 60$ kΩ

Example 8.6: For the monostable multivibrator shown in Fig. 8.1, $R_1 = R_2 = R$ = 20 kΩ, C = 0.01 μF, R_C = 2kΩ, V_{CC} = 12 V, V_{BB} = −12 V. Find the time period T.

Solution:

Time period $T = 0.69RC = 0.69 \times 20 \times 10^3 \times 0.01 \times 10^{-6} = 138\,\mu$s

Example 8.9: Design a collector-coupled monostable multivibrator shown in Fig. 8.15(a) to obtain an output pulse of amplitude 10 V. Given that $I_{C(\text{sat})} = 10$ mA, $I_{B2} = 2I_{B2(\text{min})}$, $V_{CE(\text{sat})} = 0.1$ V, $V_{BE(\text{sat})} = 0.3$ V, $h_{FE(\text{min})} = 40$ and a pulse of duration 1000 μs is required. $V_{BE(\text{cut-off})} = -1$ V

Solution:

As the pulse amplitude is 10 V, choose $V_{CC} = 10$ V.

$$R_C = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C(\text{sat})}} = \frac{10 - 0.1}{10\,\text{mA}} = \frac{9.9\,\text{V}}{10\,\text{mA}} = 990\,\Omega$$

Choosing $R_C = 1$ kΩ:

$$R = \frac{V_{CC} - V_\sigma}{I_{B2}}$$

$$I_{B2(\text{min})} = \frac{I_{C(\text{sat})}}{h_{FE(\text{min})}} = \frac{10\,\text{mA}}{40} = 0.25\,\text{mA}$$

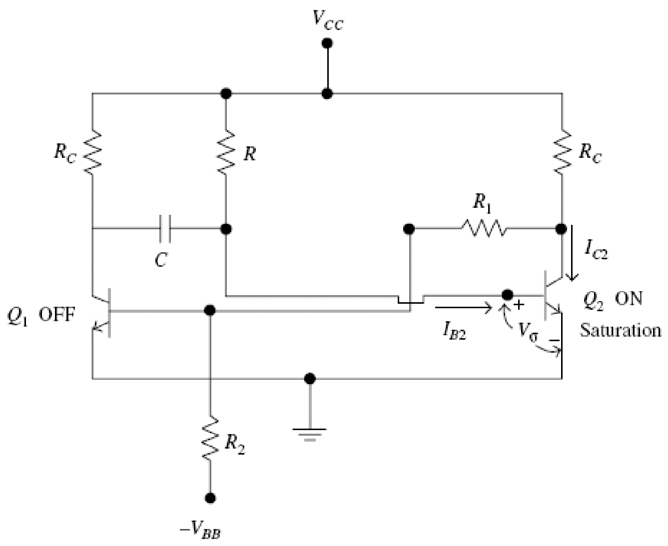

FIGURE 8.15(a) The given circuit of the monostable multivibrator

We want,

$I_{B2} = 2 \times I_{B2(\text{min})} = 2 \times 0.25 = 0.5$ mA

Therefore,

$$R = \frac{10 - 0.3}{0.5} = \frac{9.7\,\text{V}}{0.5\,\text{mA}} = 19.4\,\text{k}\Omega.$$

Choose $R = 20$ kΩ

$T = 0.69RC$

$$1000 \times 10^{-6} = 0.69 \times 20 \times 10^{3} \times \boldsymbol{C}$$

Therefore,

$$C = \frac{10^{-6}}{13.8} = 0.072\ \mu\text{F}$$

For the value of $\boldsymbol{V_{BB}}$ to be fixed, consider the Fig. 8.15(b).

If $\boldsymbol{V_{BE}}_{\text{(cut-off)}} = -1$ V

$$I_2 = \frac{V_{CE\,(\text{sat})} - (-V_{BB})}{R_1 + R_2}$$

If $\boldsymbol{R}_1 = \boldsymbol{R}_2 = \boldsymbol{R}$

$$I_2 = \frac{0.1 + V_{BB}}{2R}$$

Also:

$$I_2 = \frac{V_{B1} - (-V_{BB})}{R_2} \qquad I_2 = \frac{-1 + V_{BB}}{R_2}$$

$$\therefore \frac{0.1 + V_{BB}}{2R} = \frac{-1 + V_{BB}}{R}$$

$0.1 + \boldsymbol{V_{BB}} = 2(-1 + \boldsymbol{V_{BB}})$

$0.1 + \boldsymbol{V_{BB}} = -2 + 2\boldsymbol{V_{BB}}$ $\qquad$ $\boldsymbol{V_{BB}} = 2.1$ V

To find $\boldsymbol{R}_1 = \boldsymbol{R}_2$,

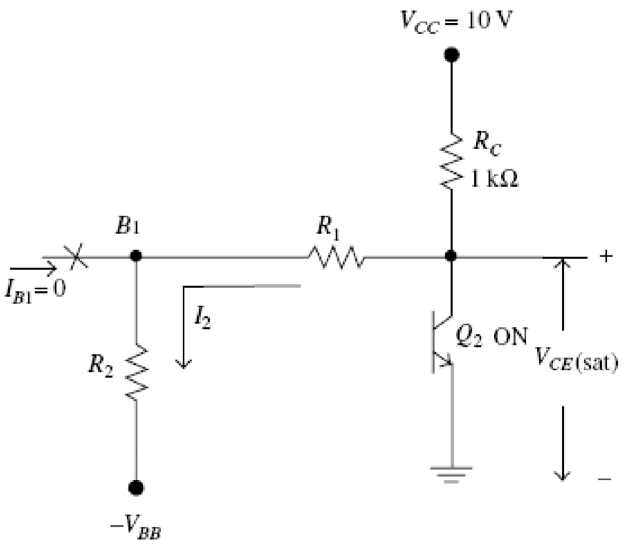

FIGURE 8.15(b) The circuit to calculate V_{BB}

$$I_2 = \frac{1}{10} I_{C(\text{sat})} = \frac{10}{10} = 1\,\text{mA}$$

Therefore,

$$R_1 + R_2 = \frac{V_{CE(\text{sat})} + V_{BB}}{I_2} = \frac{0.1 + 2.1}{1\,\text{mA}} = 2.2\,\text{k}\Omega$$

$\boldsymbol{R_1} = \boldsymbol{R_2} = 1.1\ \text{k}\Omega$.

Example 8.10: Design the circuit for the collector-coupled monostable multivibrator shown in Fig. 8.16. Given that: $\boldsymbol{I_{C(\text{sat})}} = 5$ mA, $\boldsymbol{V_{B(\text{OFF})}} = -1.5$ V, $\boldsymbol{C_i} = 20$ pF. It is required to generate a pulse having a width of 5000 μs. $\boldsymbol{I_{B(\text{sat})}} = 1.5 \times \boldsymbol{I_{B(\text{min})}}$. Neglect junction voltages and assume $\boldsymbol{h_{FE}}(\text{min}) = 20$.

Solution: We have

$$R_C = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C(\text{sat})}} = \frac{V_{CC}}{I_{C(\text{sat})}} = \frac{15}{5} = 3\,\text{k}\Omega$$

$$I_{B2(\text{min})} = \frac{I_{C2(\text{sat})}}{h_{\text{FE}}} = \frac{5}{20} = 0.25\,\text{mA}.$$

$\boldsymbol{I_{B2(\text{sat})}} = 1.5 \times \boldsymbol{I_{B2(\text{min})}} = 1.5 \times 0.25 = 0.375$ mA

$$R = \frac{V_{CC} - V_{\sigma}}{I_{\text{B2(sat)}}} = \frac{V_{CC}}{I_{\text{B2(sat)}}} = \frac{15}{0.375} = 40\,\text{k}\Omega$$

$\boldsymbol{R} = 40$ kΩ

Given

$\boldsymbol{T} = 5000\ \mu$s and $\boldsymbol{T} = 0.69\boldsymbol{RC}$

$$C = \frac{T}{0.69 \times R} = \frac{5000 \times 10^{-6}}{0.69 \times 40 \times 10^3} = 181.16\,\text{nF}$$

Given that

$\boldsymbol{V_{B1(\text{OFF})}} = -1.5$ V:

$$V_{B1(\text{OFF})} = \frac{V_{CE(\text{sat})} \times R_2}{R_1 + R_2} + \frac{(V_{BB})R_1}{R_1 + R_2} = \frac{(V_{BB})R_1}{R_1 + R_2} \quad \text{as the first term is small.}$$

$$-1.5 = V_{BB} \times \frac{40}{40 + 40} = 0.5\,V_{BB}$$

Therefore,

$V_{BB} = -3$ V

In the quasi-stable state when Q_1 goes into saturation:

$I_{B1(\text{sat})} = I_1 - I_2$

Since junction voltages are negligible:

$$I_{B1(\text{sat})} = \frac{V_{CC} - V_\sigma}{R_C + R_1} - \frac{V_\sigma + V_{BB}}{R_2} = \frac{V_{CC}}{R_C + R_1} - \frac{V_{BB}}{R_2}$$

Since $R_1 = R_2$, the above equation reduces to:

$$0.375 = \frac{15}{3 + R_1} - \frac{3}{R_1}$$

$$\therefore \qquad 0.375R_1^2 - 10.875R_1 + 9 = 0$$

$$R_1 = \frac{10.8 \pm \sqrt{(10.8)^2 - (4 \times 0.375 \times 9)}}{2 \times 0.375}$$

From this $R_1 = 28$ kΩ or 0.85 kΩ.

Choose $R_1 = R_2 = 28$ kΩ.

Further, given that $C_i = 20$ pF:

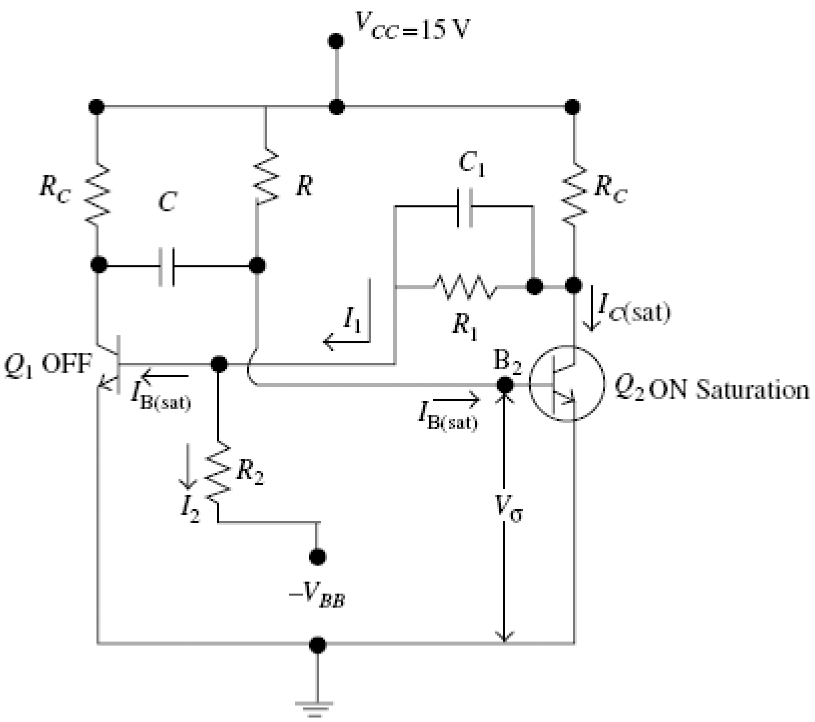

FIGURE 8.16 Monostable multivibrator

Therefore,

$$C_1 = \frac{R_2 C_i}{R_1} = 20\,\text{pF}.$$

In the absence of any specification of C_i, C_1 is calculated as $R_1C_1 = 1\ \mu$s.

In which case,

$$C_1 = \frac{1 \times 10^{-6}}{40 \times 10^3} = 25\,\text{pF}$$

UNSOLVED PROBLEMS

1. A monostable multivibrator is used as a voltage-to-time converter. Find the time period if R = 10 kΩ, C = 0.01 μF, V_{BB}/V_{CC} = 0.5.
2. Design a collector-coupled monostable multivibrator using an n–p–n silicon transistor with $h_{FE(\text{min})}$ = 40, $V_{BE(\text{cut Off})} \approx$ 0 V and $I_{B(\text{sat})} = 1.5 I_{B(\text{min})}$. Given that: V_{CC} = 10 V, $I_{C(\text{sat})}$ = 5 mA, $R_{C1} = R_{C2} = R_C$, $V_{CE(\text{sat})}$ = 0.2 V and $V_{BE(\text{sat})}$ = 0.7 V. If the pulse width required is 1 ms, calculate the value of C.
3. A collector-coupled monostable multivibrator shown in Fig. 8p.1 using Ge n–p–n transistors has the following parameters: V_{CC} = 9 V, V_{BB} = 9 V, R_C = 2 kΩ, R_1 = 10 kΩ, R_2 = 20 kΩ, R = 10 kΩ, h_{FE} = 40, $r_{bb'}$ = 0.2 kΩ, C = 0.001 μF, $V_{CE(\text{sat})}$ = 0.1 V and V_σ = 0.3V.
   a) Calculate and plot the waveforms.
   b) Find the pulse width.

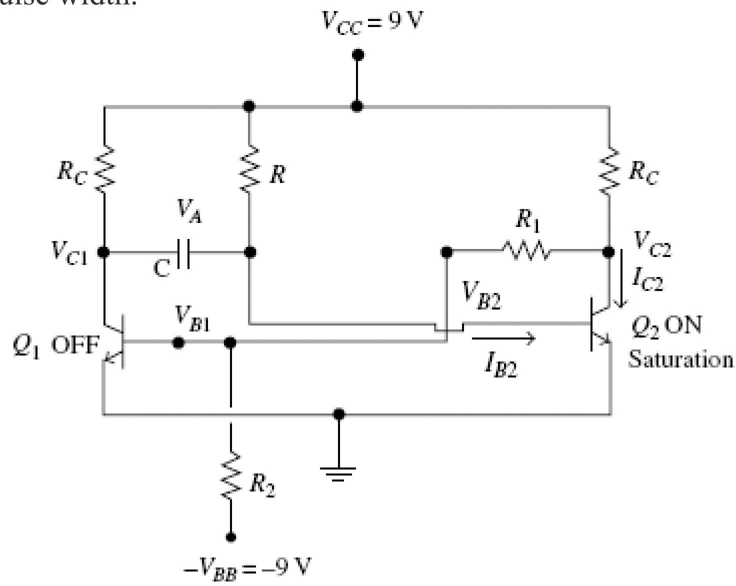

FIGURE 8p.1 The given circuit of the monostable multivibrator

4. For a collector-coupled monostable multivibrator circuit shown in Fig. 8.1, $R_1 = R_2 = R$ = 10 kΩ, C = 0.01 μF, R_C = 1 kΩ, V_{CC} = 10 V, h_{FE} = 20. In the quasi-stable state Q_1 is in the

active region with collector current of 2 mA. Find the time period and the value of V_{BB}. Neglect junction voltages. $I_B(\text{sat}) = 1.5\, I_{B(\text{min})}$.

5. An emitter-coupled monostable multivibrator shown in Fig. 8p.2 has the following parameters: $V_{CC} = 6$V, $R_{C1} = R_{C2} = R_E = 3$ kΩ, $R = 50$ kΩ, $V = 2.8$ V and $C = 0.01$ μF and ***n–p–n*** silicon transistors with $h_{FE} = 50$ and $r_{bb'} = 100$ Ω are used. A trigger is applied at $t = 0$.

a) Assume that Q_1 is OFF and Q_2 is ON at $t = 0-$. Calculate the node voltages. Using your calculated values verify that Q_1 is indeed OFF and Q_2 is in saturation.
b) Assume that Q_1 is in the active region and Q_2 is OFF at $t = 0+$. Calculate the node voltage and verify that Q_1 is indeed in the active region and Q_2 is OFF.
c) Calculate the node voltages at $t = T-$.
d) Calculate the node voltages at $t = T+$.

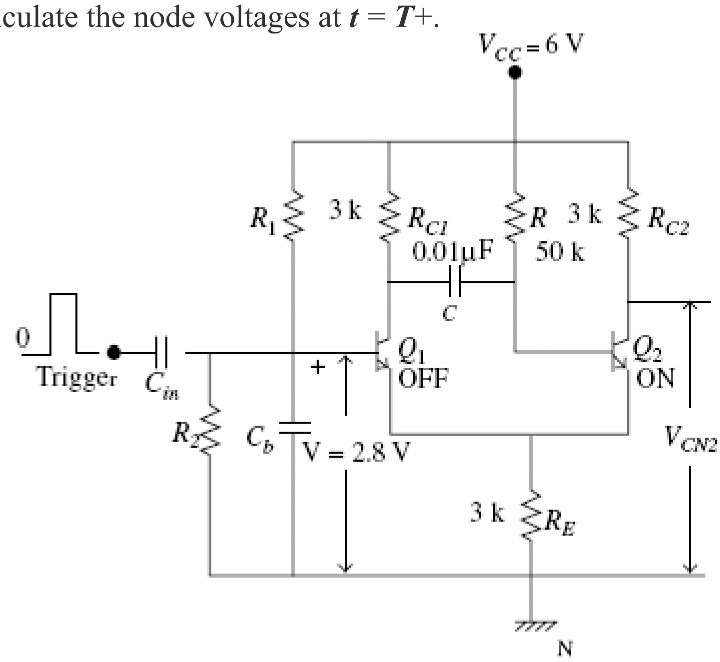

FIGURE 8p.2 Emitter–coupled monostable multivibrator

6. An emitter-coupled monostable multivibrator has the following parameters: $V_{CC} = 15$ V, $R_{C1} = R_{C2} = R_E = 4$ kΩ, $R = 100$ kΩ, $V = 5$ V and $C = 0.01$ μF and an ***n–p–n*** silicon transistor with $h_{FE(\text{min})} = 40$ and $r_{bb'} = 100$ Ω is used. Calculate and plot the waveforms to scale.