Chapter-7
Astable Multivibrators

1. For the multivibrator in Fig.7p.1, $R_1 = R_2 = R = 47\ \text{k}\Omega$, $C_1 = C_2 = C = 0.01\ \mu$F. Find the time period and frequency.

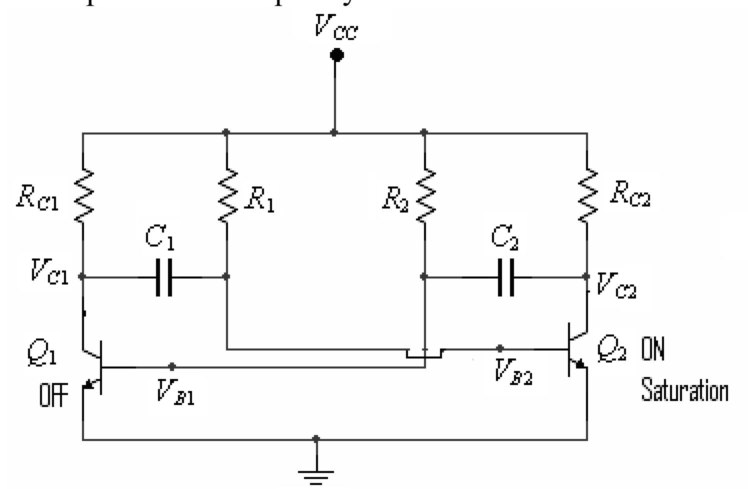

Fig.7p.1 Un-symmetric astable multivibrator

Solution:
Given $R_1 = R_2 = R = 47\ \text{k}\Omega, C_1 = C_2 = 0.01\ \mu$F.

This is a symmetric astable multivibrator.

$T = 1.38RC = 1.38 \times 47 \times 10^3 \times 0.01 \times 10^{-6} = 0.648\ \text{ms}$

$f = \dfrac{1}{T} = \dfrac{1}{0.648 \times 10^{-3}} = 1.54$ kHz.

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2. For the astable multivibrator in Fig.7p.1, $R_1 = 20\ \text{k}\Omega$, $R_2 = 30\ \text{k}\Omega, C_1 = C_2 = C = 0.01\ \mu$F. Find the time period, duty cycle and the frequency.

Solution:
This is an un-sy*m*metric astable multivibrator.

$T_2 = 0.69R_1C_1 = 0.69 \times 20 \times 10^3 \times 0.01 \times 10^{-6} = 0.2\ \text{ms}$

$T_1 = 0.69R_2C_2 = 0.69 \times 30 \times 10^3 \times 0.01 \times 10^{-6} = 0.138\ \text{ms}$

$T = T_1 + T_2 = 0.138 + 0.2 = 0.338\ \text{ms}$

per cent $D = \dfrac{T_1}{T} \times 100$ per cent $= \dfrac{0.138}{0338} \times 100$ per cent = 59.17 per cent

$f = \dfrac{1}{T} = \dfrac{1}{0.338 \times 10^{-3}} = 2.95$ kHz.

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3. For the symmetric astable multivibrator that generates square waves with vertical edges shown in Fig.7p.3, V_{CC}=10 V, $R_C = R_3 = 2\ \text{k}\Omega$, $R_1 = R_2 = 20\ \text{k}\Omega$, $C = 0.1\ \mu\text{F}$, $h_{FE(\min)} = 30$. Show that the ON device is in saturation. Also find f. Assume suitable values for $V_{CE(\text{sat})}$ and $V_{BE(\text{sat})}$. Si transistors are used.

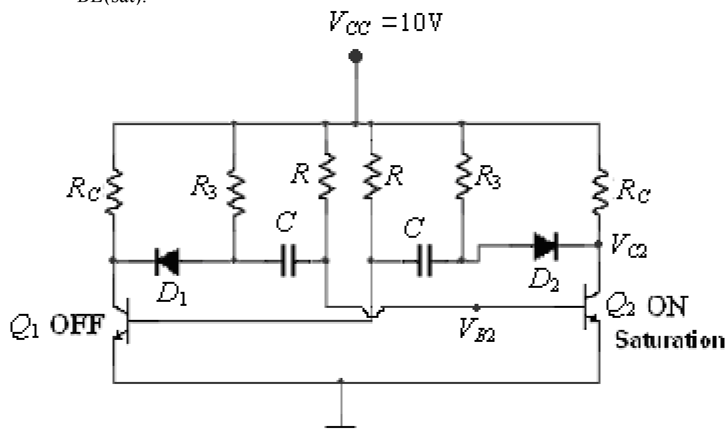

Fig.7p.3 Astable multivibrator with vertical edges

Solution:

Assume Q_1 is OFF and Q_2 is ON and in saturation. If Q_2 is ON and in saturation, for silicon transistors, $V_{C2} = V_{CE(\text{sat})} = 0.2$ V, $V_{B2} = V_\sigma = 0.7$ V then D_2 is ON. The collector load is $R_3 // R_C$.

$$R_C^{'} = R_3 // R_C = \frac{2\times 2}{4} = 1\ \text{k}\Omega$$

$$I_{C2} = \frac{V_{CC} - V_{CE(\text{sat})}}{R_C^{'}} = \frac{10-0.2}{1\ \text{k}\Omega} = \frac{9.8}{1\times 10^3} = 9.8\ \text{mA}$$

$$I_{B2} = \frac{V_{CC} - V_\sigma}{R} = \frac{10-0.7}{20\ \text{k}\Omega} = \frac{9.3}{20\times 10^3} = 0.465\ \text{mA}$$

$$I_{B2\min} = \frac{I_{C2}}{h_{FE\min}} = \frac{9.8\ \text{mA}}{30} = 0.326\ \text{mA}$$

$I_{B2} >> I_{B2\min}$

Hence Q_2 is in saturation.

To find f:

For a symmetric astable multivibrator: $f = \dfrac{0.7}{RC} = \dfrac{0.7}{20\times 10^3 \times 0.1\times 10^{-6}} = 350$ Hz

4. Design a symmetric collector-coupled astable multivibrator to generate a square wave of 10 kHz having peak-to-peak amplitude of 10 V where $h_{FE\text{min}} = 30$, $V_{CE(\text{sat})} = 0.2$ V, $I_{C(\text{sat})} = 2$ mA.

Solution:

Given $V_{CE(\text{sat})} = 0.2$ V, $V_{BE(\text{sat})} = V_{\sigma} = 0.7$ V, $I_{C(\text{sat})} = 2$ mA, $f = 2$ kHz, $h_{FE\text{min}} = 30$.

As the output amplitude is specified as 12 V, choose $V_{CC} = 12$ V.

As $f = 2$ kHz,

$$\therefore T = \frac{1}{f} = \frac{1}{10 \times 10^3} = 0.1 \text{ ms}$$

The astable is symmetric, hence

$R_1 = R_2 = R$ and $C_1 = C_2 = C$

$$T_1 = T_2 = \frac{T}{2} = \frac{0.1}{2} = 0.05 \text{ ms}$$

To calculate R_{C2}:

$$R_{C2} = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C(\text{sat})}} = \frac{10 - 0.2}{2 \times 10^{-3}} = 4.9 \text{ k}\Omega$$

$R_{C1} = R_{C2} = 4.9$ kΩ.

To calculate R_2:

$$R_2 = \frac{V_{CC} - V_{\sigma}}{I_{B2(\text{sat})}}$$

$$I_{B2\,\text{min}} = \frac{I_{C(\text{sat})}}{h_{FE\,\text{min}}} = \frac{2 \text{ mA}}{30} = 0.066 \text{ mA}$$

If Q_2 is in saturation

$$I_{B2(\text{sat})} = 1.5 I_{B2(\text{min})}$$

$$= 1.5 \times 0.066 = 0.099 \text{ mA}$$

$$R_2 = \frac{10 - 0.7}{0.099 \times 10^{-3}} = 93.9 \text{ k}\Omega$$

$R_1 = R_2 = 93.9$ kΩ

As $C_1 = C_2$

$T_1 = 0.69 R_2 C_2$

$$C_2 = \frac{0.05 \times 10^{-3}}{0.69 \times 93.9 \times 10^3} = 771.7 \text{ pF}$$

$C_1 = C_2 =$ 771.7 pF

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5. Design an un-symmetric astable multivibrator having duty cycle of 40 per cent. It is required to oscillate at 5 kHz. Ge transistors with $h_{\text{FE}} = 40$ are used. The amplitude of the square wave is required to be 20 V. $I_{\text{C}} = 5$ mA, $V_{CE(\text{sat})} = 0.1$ V and $V_{BE(\text{sat})} = 0.3$ V.

Solution:

For Ge transistors, $V_{CE(\text{sat})} = 0.1$ V, $V_{BE(\text{sat})} = V_{\sigma} = 0.3$ V

Given $I_{C(\text{sat})} = 5$ mA, $f = 5$ kHz, $h_{FE\min} = 40$, duty cycle = 40 per cent.
As the output amplitude is specified as 20 V, choose $V_{CC} = 20$ V.
As $f = 5$ kHz,

$$\therefore T = \frac{1}{f} = \frac{1}{5\times10^{3}} = 0.2 \text{ ms}$$

The astable is unsymmetric, hence

$$T_1 \neq T_2$$

i.e. $R_1C_1 \neq R_2C_2$
choose $C_1 = C_2 = C$
then $R_1 \neq R_2$

$$\text{Duty cycle} = \frac{T_1}{T_1+T_2} = \frac{T_1}{T}$$

$$0.4 = \frac{T_1}{0.2\times10^{-3}}$$

$$T_1 = 0.4\times0.2\times10^{-3} = 0.08 \text{ ms}$$

$$T_2 = T - T_1 = 0.2 - 0.08 = 0.12 \text{ ms}$$

To calculate R_{C2}:

$$R_{C2} = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C(\text{sat})}} = \frac{20-0.1}{5 \text{ mA}} = 3.98 \text{ k}\Omega$$

Choose $R_{C1} = R_{C2} = 3.98 \text{ k}\Omega = R_C$
To calculate R_2:

$$R_2 = \frac{V_{CC} - V_{\sigma}}{I_{B2(\text{sat})}}$$

$$I_{B2\min} = \frac{I_{C(\text{sat})}}{h_{FE\min}} = \frac{5 \text{ mA}}{40} = 0.125 \text{ mA}$$

If Q_2 is in saturation

$$I_{B2(\text{sat})} = 1.5 I_{B2(\min)}$$

$$= 1.5\times0.125 \text{ mA} = 0.187 \text{ mA}$$

$$\therefore R_2 = \frac{20-0.3}{0.187\times10^{-3}} = 105.3 \text{ k}\Omega$$

As $C_1 = C_2 = C$

$$T_1 = 0.69 R_2 C_2$$

$$C_2 = \frac{T_1}{0.69R_2} = \frac{0.08\times10^{-3}}{0.69\times105.3\times10^{3}} = 1.1 \text{ nF}$$

$$C_1 = C_2 = 1.1 \text{ nF}$$

$$T_2 = 0.69 R_1 C_1$$

$$0.12\times10^{-3} = 0.69 R_1 \times 1.1\times10^{-9}$$

$$R_1 = \frac{0.12\times10^{-3}}{0.69\times1.1\times10^{-9}} = 158.1 \text{ k}\Omega$$

$$h_{FE}R_C = 40\times3.98 \text{ k}\Omega = 159 \text{ k}\Omega$$

The values R_1 and R_2 are less than $h_{FE}R_C$. Hence the devices Q_1 and Q_2 are in saturation, when ON.

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6. For an un-symmetric astable multivibratorR_1 = 100 kΩ, R_2 = 100 kΩ, C_1 = 0.02 μF, C_2 = 0.01μF. Find the frequency of oscillation and the duty cycle.

Solution:

$$T_2 = 0.69R_1C_1 = 0.69\times100\times10^3\times0.02\times10^{-6} = 1.38 \text{ ms}$$

$$T_1 = 0.69R_2C_2 = 0.69\times100\times10^3\times0.01\times10^{-6} = 0.69 \text{ ms}$$

$$T = T_1 + T_2 = 0.69 + 1.38 = 2.09 \text{ ms}$$

$$f = \frac{1}{T} = \frac{1}{2.09\times10^{-3}} = 483 \text{ Hz}$$

$$\text{per cent } D = \frac{T_1}{T}\times100 \text{ per cent} = \frac{0.69}{2.09\times10^{-3}}\times100 \text{ per cent} = 33 \text{ per cent}.$$

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7. Design an unsymmetrical astable multivibrator shown in Fig.7p.1 using silicon *n–p–n* transistors having an output amplitude of 12 V. Given data,
$I_{C(\text{sat})}$ = 5 mA, $h_{FE\min}$ = 50, f = 5 kHz, duty cycle = 0.6.

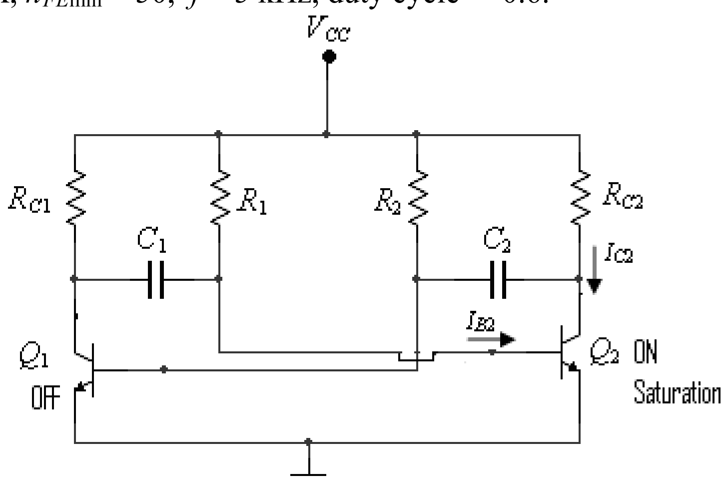

Fig.7p.1 Un-symmetric astable multivibrator

Solution:

Assume $V_{CE(\text{sat})}$ = 0.2 V

$$V_{BE(\text{sat})} = V_\sigma = 0.7 \text{ V}$$

Given $I_{C(\text{sat})}$ = 5 mA, f = 2 kHz, $h_{FE\min}$ = 50, duty cycle = 0.6.

As the output amplitude is specified as 12 V, choose V_{CC} = 12 V.

As f = 2 kHz,

$$\therefore T = \frac{1}{f} = \frac{1}{2\times10^3} = 0.5 \text{ ms}$$

The astable is unsymmetric, hence

$$T_1 \neq T_2$$

i.e. $R_1C_1 \neq R_2C_2$
choose $C_1 = C_2 = C$
then $R_1 \neq R_2$

Duty cycle = $\dfrac{T_1}{T_1 + T_2} = \dfrac{T_1}{T}$

$0.6 = \dfrac{T_1}{T}$

$T_1 = 0.6T = 0.6 \times 0.5 = 0.3$ ms

$T_2 = T - T_1 = 0.5 - 0.3 = 0.2$ ms

To calculate R_{C2}:

$$R_{C2} = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C(\text{sat})}} = \frac{12 - 0.2}{5 \text{ mA}} = \frac{11.8}{5 \text{ mA}}$$

$R_{C2} = 2.36$ kΩ

Choose $R_{C1} = R_{C2} = 2.2$ kΩ $= R_C$.

To calculate R_2:

$$R_2 = \frac{V_{CC} - V_\sigma}{I_{B2(\text{sat})}}$$

$$I_{B2\min} = \frac{I_{C(\text{sat})}}{h_{FE\min}} = \frac{5 \text{ mA}}{50}$$

$= 0.1$ mA

If Q_2 is in saturation

$I_{B2(\text{sat})} = 1.5 I_{B2(\min)}$

$= 1.5 \times 0.1 = 0.15$ mA

$$\therefore R_2 = \frac{12 - 0.7}{0.15} = \frac{11.3 \text{ V}}{0.15 \text{ mA}} = 75.3 \text{ k}\Omega$$

As $C_1 = C_2 = C$

$T_1 = 0.69 R_2 C$

$0.3 \text{ ms} = 0.69 \times 75.3 \text{ k}\Omega \times C$

$$C = \frac{0.3 \times 10^{-3}}{0.69 \times 75.3 \times 10^3} = 5.77 \text{ nF}$$

$T_2 = 0.69 R_1 C$

$0.2 \times 10^{-3} = 0.69 R_1 \times 5.77 \times 10^{-9}$

$$R_1 = \frac{0.2 \times 10^{-3}}{0.69 \times 5.77 \times 10^{-9}} = 50 \text{ k}\Omega$$

$h_{FE}R_C = 50 \times 2.2 \text{ K} = 110 \text{ K}$

The values R_1 and R_2 are less than $h_{FE}R_C$. Hence the devices Q_1 and Q_2 are in saturation, when ON.

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8. A Voltage-to-frequency converter shown in Fig.7p.2 generates oscillations at a frequency f_1 when $V_{BB} = V_{CC}$. Find the ratio of V_{CC}/V_{BB} at which the frequency $f_2 = 4f_1$.

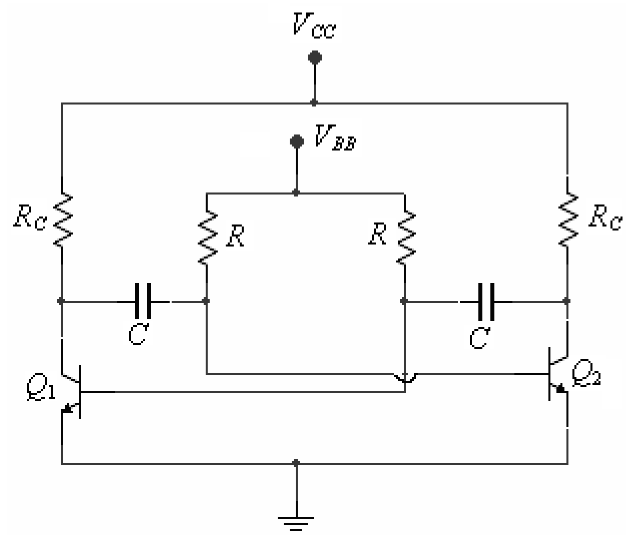

Fig.7p.2 Voltage-to-frequency converter

Solution:

From Eq.(7.30), the expression for the frequency of oscillations is

$$f = \frac{1}{2\tau \ln(1 + \frac{V_{CC}}{V_{BB}})}$$

Case1: The frequency of oscillations is f_1 when $V_{CC} = V_{BB}$

$$\therefore f_1 = \frac{1}{2\tau \ln(1+1)} = \frac{1}{2\tau \ln 2}$$

Case 2: If a new frequency $f_2 = 4f_1$ is desired.

$$f_2 = \frac{1}{2\tau \ln(1 + \frac{V_{CC}}{V_{BB}})}$$

$$f_2 = 4 f_1$$

$$= 4 \times \frac{1}{2\tau \ln 2} = \frac{2}{\tau \ln 2}$$

$$\frac{2}{\tau \ln 2} = \frac{1}{2\tau \ln(1 + \frac{V_{CC}}{V_{BB}})}$$

$$\ln 2 = 4 \ln(1 + \frac{V_{CC}}{V_{BB}})$$

$$\ln(1 + \frac{V_{CC}}{V_{BB}})^4 = \ln 2$$

Taking antilog

$$(1+\frac{V_{CC}}{V_{BB}})^4 = 2$$

$$(1+\frac{V_{CC}}{V_{BB}})^2 = \sqrt{2} = 1.414$$

$$1+\frac{V_{CC}}{V_{BB}} = \sqrt{1.414} = 1.189$$

$$\frac{V_{CC}}{V_{BB}} = 1.189 - 1 = 0.189$$

