ASTABLE MULTIVIBRATOR

- As the name indicates an astable multivibrator is a multivibrator with no permanent stable state. Both of its states are quasi stable only. It cannot remain in any one of its states indefinitely and keeps on oscillating between its two quasi stable states the moment it is connected to the supply. It remains in each of its two quasi stable states for only a short designed interval of time and then goes to the other quasi stable state. No triggering signal is required. Both the coupling elements are capacitors (ac coupling) and hence both the states are quasi stable. It is a free running multivibrator. It generates square waves. It is used as a master oscillator.

There are two types of astable multivibrators:

1. Collector-coupled astable multivibrator
2. Emitter-coupled astable multivibrator

THE COLLECTOR-COUPLED ASTABLE MULTIVIBRATOR

- Figure 1 shows the circuit diagram of a collector-coupled astable multivibrator using n-p-n transistors. The collectors of both the transistors Qj and Q2 are connected to the bases

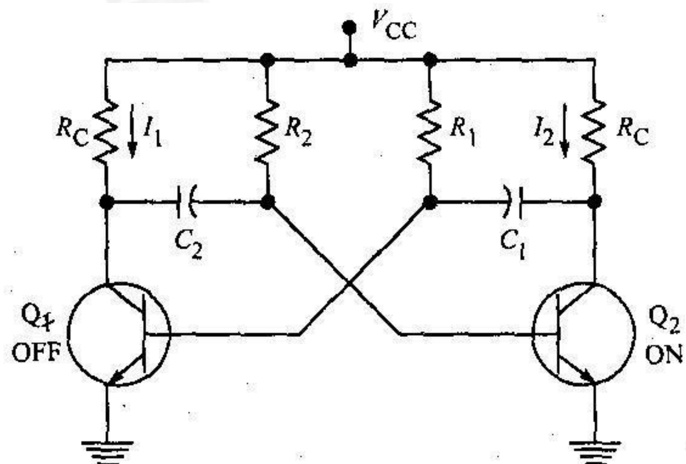

Figure 1 A collector-coupled astable multivibrator.

of the other transistors through the coupling capacitors C_S and C_2. Since both are ac couplings, neither transistor can remain permanently at cut-off. Instead, the circuit has two quasi-stable states, and it makes periodic transitions between these states. Hence it is used as a master oscillator. No triggering signal is required for this multivibrator. The component values are selected such that, the moment it is connected to the supply, due to supply transients one transistor will go into saturation and the other into cut-off, and also due to capacitive couplings it keeps on-oscillating between its two quasi stable states.

The waveforms at the bases and collectors for the astable multivibrator, are shown in Figure 4.54. Let us say at t = 0, Q_2 goes to ON state and Q] to OFF state. So, for t < 0, Q_2 was OFF and Qi was ON. Hence

for t < 0, v_{B2} is negative, $v_{C2} = V_{cc}$, $V_{B!} = V_{BE}(sat)$ and $v_{cj} = V_{CE}(sat)$. The capacitor C_2 charges from V_{cc} through R_2 and v_{B2} rises exponentially towards V $_{cc}$. At t = 0, v_{B2} reaches the cut-in voltage V_y and Q_2

conducts. As Q_2 conducts, its collector voltage V_{c2} drops by /2/?c - ^cc ~ VcE(^{sa}O- This drop in v_{c2} is

transmitted to the base of Qj through the coupling capacitor C_2 and hence v_{B1} also falls by /2/?c- Qi goes to OFF state. So, $V_{B]} = V_{BE}(sat)$ - /2tf$_c$, and its collector voltage v_{cl} rises towards V_{C}c- This rise in $v_{c]}$ is coupled through the coupling capacitor C_2 to the base of Q_2, causing an overshoot § in v_{B2} and the abrupt rise by the same amount 8 in VCL as shown in Figure 4.51(c). Now since Q_2 is ON, C\ charges from V_{cc} through R_{lt} and hence $V_{B]}$ rises exponentially. At t = 7"], when $V_{B!}$ rises to V_Y, Qi conducts and due to regenerative action Qi goes into saturation and Q_2 to cut-off. Now, for t > T\, the coupling capacitor C_2 charges from V_{cc} through R_2 and when v_{B2} rises to the cut-in voltage V_r, Q_2

conducts and due to regenerative feedback Q2 goes to ON state and Q| to OFF state. The cycle of events repeats and the circuit keeps on oscillating between its two quasi-stable states. Hence the output is a square wave. It is called a square wave generator or square wave oscillator or relaxation oscillator. It is a free running oscillator.

Expression for the frequency of oscillation of an astable multivibrator

Consider the waveform at the base of Q_1 shown in Figure 4.54(d). At $t = 0$,

$$v_{B1} = V_{BE}(sat) - I_2R_C$$

But $$I_2R_C = V_{CC} - V_{CE}(sat)$$

$\therefore$ $$\text{At } t = 0,\ v_{B1} = V_{BE}(sat) - V_{CC} + V_{CE}(sat)$$

For $0 < t < T_1$, v_{B1} rises exponentially towards V_{CC} given by the equation,

$$v_o = v_f - (v_f - v_i)e^{-t/\tau}$$

$\therefore$ $$v_{B1} = V_{CC} - [V_{CC} - (V_{BE}(sat) - V_{CC} + V_{CE}(sat))]e^{-t/\tau_1}, \text{ where } \tau_1 = R_1C_1$$

At $t = T_1$, when v_{B1} rises to V_γ, Q_1 conducts

$\therefore$ $$V_\gamma = V_{CC} - [2V_{CC} - (V_{BE}(sat) + V_{CE}(sat))]e^{-T_1/R_1C_1}$$

or $$e^{T_1/R_1C_1} = \frac{2\left[V_{CC} - \dfrac{V_{BE}(sat) + V_{CE}(sat)}{2}\right]}{V_{CC} - V_\gamma}$$

$$T_1 = R_1C_1 \ln \frac{2\left[V_{CC} - \dfrac{V_{CE}(sat) + V_{BE}(sat)}{2}\right]}{V_{CC} - V_\gamma}$$

$$T_1 = R_1C_1 \ln 2 + R_1C_1 \ln \frac{\left[V_{CC} - \dfrac{V_{CE}(sat) + V_{BE}(sat)}{2}\right]}{V_{CC} - V_\gamma}$$

At room temperature for a transistor,

$$V_\gamma = \frac{V_{CE}(sat) + V_{BE}(sat)}{2}$$

$\therefore$ $$T_1 = R_1C_1 \ln 2 = 0.693R_1C_1$$

On similar lines considering the waveform of Figure 4.54(b), we can show that the time T2 for which Q2 is

OFF and Qj is ON is given by $T_2 = R_2C_2 \ln 2 = 0.693R_2C_2$ The period of the waveform,

The frequency ofoscillation,

If R{ = R2 = R, and Cs = C2 = C, then TI = T2 = 772

$$T = 2 \times 0.693RC = 1.386RC \quad \text{and} \quad f = \frac{1}{1.386RC}$$

The frequency of oscillation may be varied over the range from cycles to mega cycles by varying RC. It is also possible to vary the frequency electrically by connecting R\ and R2 to an auxiliary voltage source V (the collector supply remains $+V_{CC}$) and then varying this voltage V.

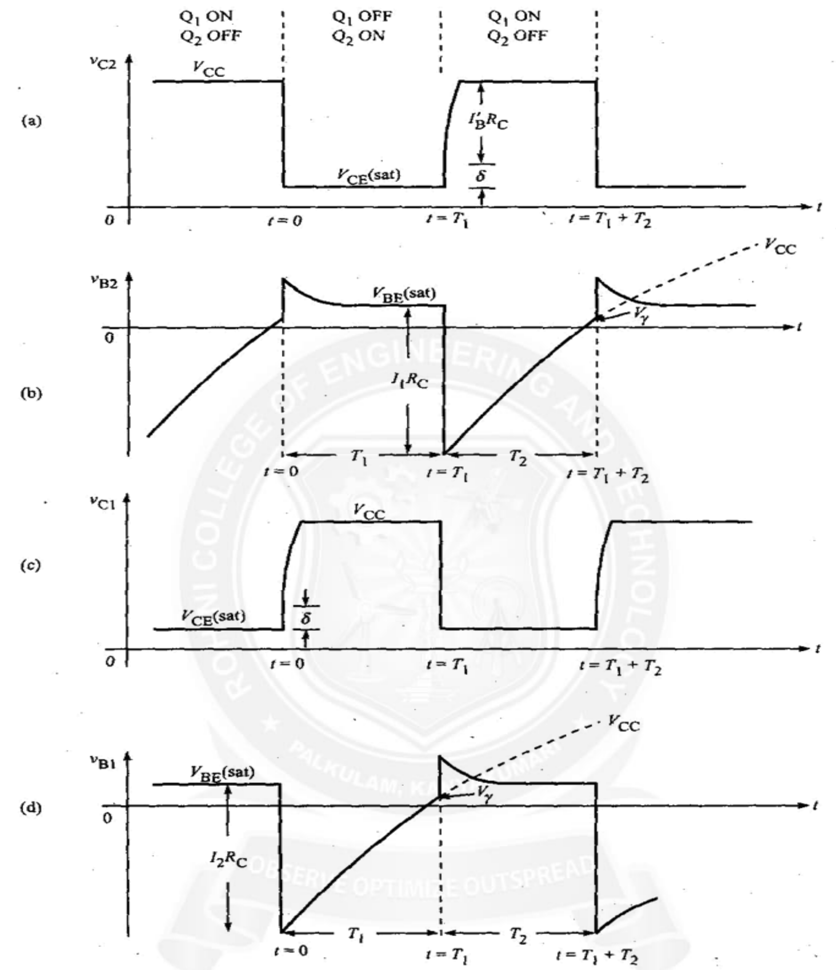

Figure 4.54 Waveforms at the bases and collectors of a collector-coupled astable multivibrator.

THE EMITTER-COUPLED ASTABLE MULTIVIBRATOR

- An emitter-coupled astable multivibrator may be obtained by using three power supplies or a single power supply.

Figure 4.63 shows the circuit diagram of a free-running emitter coupled multivibrator using n-p-n transistors. Figure 4.64 shows its waveforms. Three power supplies are indicated for the sake of simplifying the analysis. A more practical circuit using a single supply is indicated in Figure 4.65. Let us assume that the circuit operates in such a manner that Qi switches between cut-off and saturation and Q2 switches between cut-off and its active region.

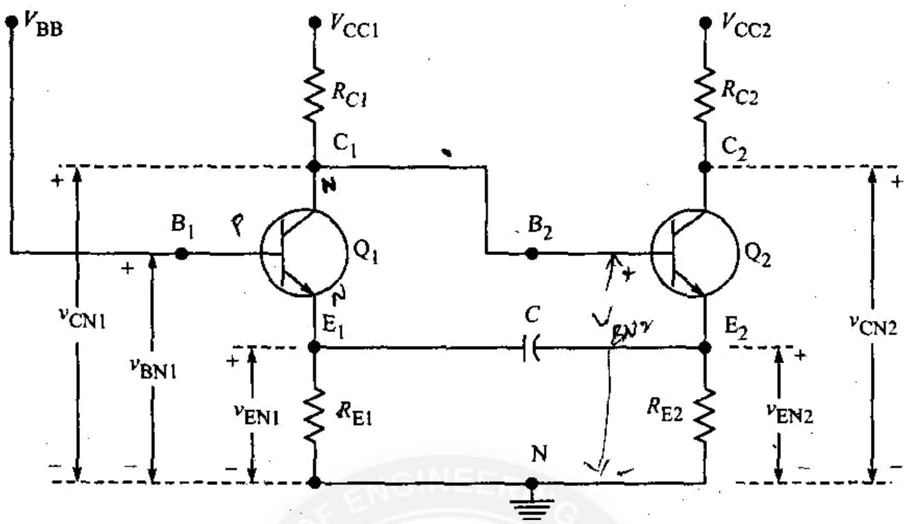

Figure 4.63 The astable emitter-coupled multivibrator.

(Source: Microelectronics byJ. Millman and A. Grabel, Page-498)

Calculations at $t = t_1^-$

Since Q_1 is ON and Q_2 is OFF just before the transition at $t = t_1^-$, we have

$$v_{CN2}(t_1^-) = V_{CC2}$$
$$v_{EN1}(t_1^-) = V_{BB} - V_{BE}(\text{sat}) = V_{BB} - V_\sigma$$
$$v_{CN1}((t_1^-) = v_{BN2} = v_{EN1} + V_{CE}(\text{sat}) = V_{BB} - V_\sigma + V_{CE}(\text{sat})$$

During the interval preceding t = t\, the capacitor C charges from a fixed voltage

^BB ~ V0 through theresistor RE2. All circuit voltages remain constant except

$$v_{EN2}(t_1^-) = v_{BN2} - V_\sigma + V_{CE}(\text{sat}) - V_\gamma$$

vEN2, which falls asymptotically towards zero.

The transistor Q2 will begin to conduct when vEN2 falls to

$$R_{C1} = \frac{R'R''}{R'+R''}$$

and $$V_{CC1} = V_{CC}\frac{R''}{R'+R''} + V_{BB}\frac{R'}{R'+R''}$$