MONOSTABLE MULTIVIBRATOR

- Figure 1 shows the circuit diagram of a collector-to-base coupled (simply called collector- coupled) monostable multivibrator using n-p-n transistors. The collector of Q2 is coupled to the base of Qi by a resistor R} (dc coupling) and the collector of Qt is coupled to the base of Q2 by a capacitor C (ac coupling). Ci is the commutating capacitor introduced to increase the speed of operation. The base of Qiis connected to -VBB through a resistor R2, to ensure that Q! is cut off under quiescent conditions.

- The base of Q2 is connected to VCc through R to ensure that Q2 is ON under quiescent conditions. In fact, R may be returned to even a small positive voltage but connecting it to Vcc is advantageous.

- The circuit parameters are selected such that under quiescent conditions, the monostable multivibrator finds itself in its permanent stable state with Q2ON (i.e. in saturation) and Q! OFF (i.e. in cut-off)- The multivibrator may be induced to make a transition out of its stable state by the application of a negativetrigger at the base of Q2 or at the collector of Q|. Since the triggering signal is applied to only one deviceand not to both the devices simultaneously, unsymmetrical triggering is employed.
- When a negative signal is applied at the base of Q2 at t ~ 0, due to regenerative action Q2 goes to OFF state and Qi goes to ON state. When Q, is ON, a current /i flows through its Rc and hence its collector voltage drops suddenly by I\RC This drop will be instantaneously

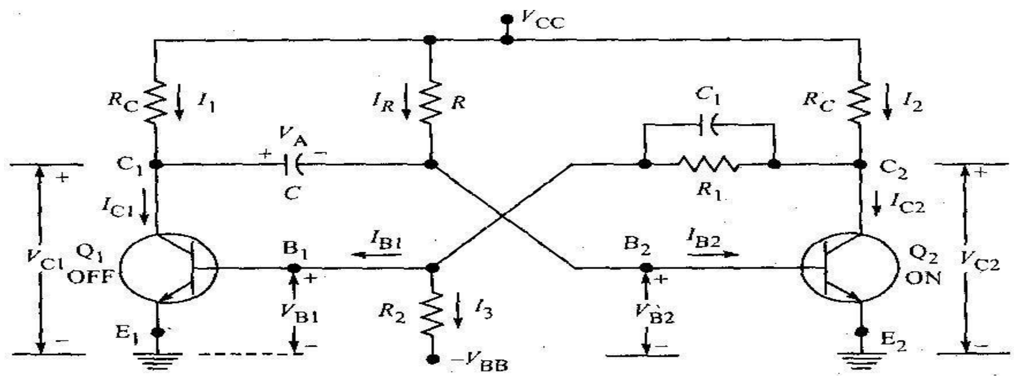

Figure 1 Circuit diagram of a collector-coupled monostable multivibrator.

transmitted through the coupling capacitor C to the base of Q2. So at t = 0^+, the base voltage of Q2 is

$$V_{BE}(sat) - I_1R_C$$

- The circuit cannot remain in this state for a long time (it stays in this state only for a finite time T) because when Qt conducts, the coupling capacitor C charges from V_{CC} through the conducting transistor Qi and $(R + R_o)C \approx RC,$

  hence the potential at the base of Q2 rises exponentially with a time constant
- where R_0 is the conducting transistor output impedance including the resistance R_C. When it passes the cut-in voltage V_γ of Q2 (at a time t = T), a regenerative action takes place turning Q| OFF and eventually returning the multivibrator to its initial stable state.

- The transition from the stable state to the quasi-stable state takes place at t = 0, and the reverse transitionfrom the quasi-stable state to the stable state takes place at t = T. The time T for which the circuit is in its quasi-stable state is also referred to as the delay time, and also as the gate width, pulse width, or pulse duration. The delay time may be varied by varying the time constant t(= RC).

Expression for the gate width T of a monostable multivibrator neglecting the

reverse saturation current /CBO

- Figure 4.42(a) shows the waveform at the base of transistor Q_2 of the monostable multivibrator shownin Figure 4.41.
- For t < 0, Q_2 is ON and so v_{B2} = V_{BE}(sat). At t = 0, a negative signal applied brings Q_2 to OFF state and Q[into saturation. A current /| flows through R_C of Q_t and hence v_{ci} drops abruptly by /|7? c volts and so v_{B2} also drops by I\R_C instantaneously. So at t - 0, v_{B2} = V_{BE}(sat) - I}R_C. For t > 0, the capacitor charges with a time constant RC, and hence the base voltage of Q_2 rises exponentially towards V_{Cc} with the same time constant. At t = T, when this base voltage rises to the cut-in voltage level Vy of the transistor, Q_2 goes to ON state, and Qj to OFF state and the pulse ends.

In the interval 0 < t < 7", the base voltage of Q_2, i.e. v_{B2} is given by

$$v_{B2} = V_{CC} - (V_{CC} - \{V_{BE}(\text{sat}) - I_1R_C\})e^{-t/\tau}$$

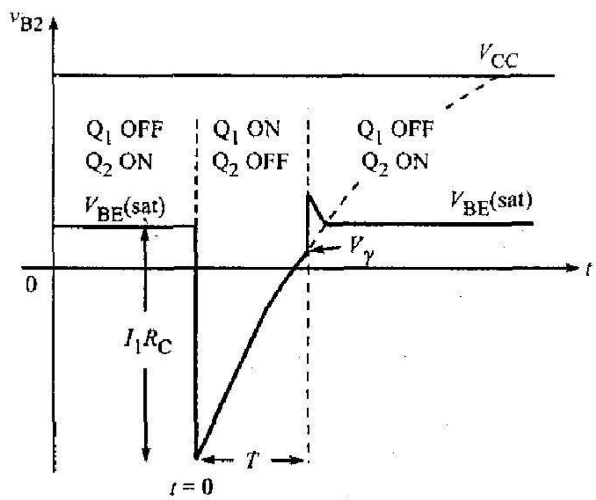

Figure 4.42(a) Voltage variation at the base of Q_2 during the quasi-stable state (neglecting /cuoX

But $I_1 R_C = V_{CC} - V_{CE}(\text{sat})$ (because at $t = 0^-$, $v_{C1} = V_{CC}$ and at $t = 0^+$, $v_{C1} = V_{CE}(\text{sat})$)

$$\therefore \quad v_{B2} = V_{CC} - [V_{CC} - \{V_{BE}(\text{sat}) - (V_{CC} - V_{CE}(\text{sat}))\}]e^{-t/\tau}$$

$$= V_{CC} - [2V_{CC} - \{V_{BE}(\text{sat}) + V_{CE}(\text{sat})\}]e^{-t/\tau}$$

At $t = T$, $v_{B2} = V_\gamma$

$$\therefore \quad V_\gamma = V_{CC} - [2V_{CC} - \{V_{CE}(\text{sat}) + V_{BE}(\text{sat})\}]e^{-T/\tau}$$

i.e.

$$e^{T/\tau} = \frac{2V_{CC} - [V_{CE}(\text{sat}) + V_{BE}(\text{sat})]}{V_{CC} - V_\gamma}$$

$$\therefore \quad \frac{T}{\tau} = \frac{\text{In}\left[2\left(V_{CC} - \frac{V_{CE}(\text{sat}) + V_{BE}(\text{sat})}{2}\right)\right]}{V_{CC} - V_\gamma}$$

i.e.

$$T = \tau \text{ In } 2 + \tau \text{ In} \frac{V_{CC} - \frac{V_{CE}(\text{sat}) + V_{BE}(\text{sat})}{2}}{V_{CC} - V_\gamma}$$

Normally for a transistor, at room temperature, the cut-in voltage is the average of the saturation junction

voltages for either Ge or Si transistors, i.e. $V_\gamma = \frac{V_{CE}(\text{sat}) + V_{BE}(\text{sat})}{2}$

Neglecting the second term in the expression for T

$$T = \tau \ln 2$$

i.e.

$$T = (R + R_o)C \ln 2 = 0.693(R + R_o)C$$

but for a transistor in saturation R_a « R.

Gate width, T = 0.693KC

- The larger the V_{CC} is, compared to the saturation junction voltages, the more accura the result is.

The gate width can be made very stable (almost independent of transistor

characteristic supplyvoltages, and resistance values) if Q_1 is driven into

saturation during the quasi-stab state.

Expression for the gate width of a monostable multivibrator considering th

reverse saturation current /CBO

- In the derivation of the expression for gate width T above, we neglected the effect of reverse saturation current /CBO on the gate width T. In fact, as the temperature increases, reverse saturation current increases and the gate width decreases.

- In the quasi-stable state when Q2 is OFF, /CBO flows out of its base through R to th supply V_{CC}. Hencethe base of Q2 will be not at V_{CC} but at V_{CC} + /CBO^> ^ C *S disconnect from the junction of the base of Q2 with the resistor R. It therefore appears that the capacitt C in effect charges through R from a source V_{CC} + /CBO^- See Figure 4.42(b).

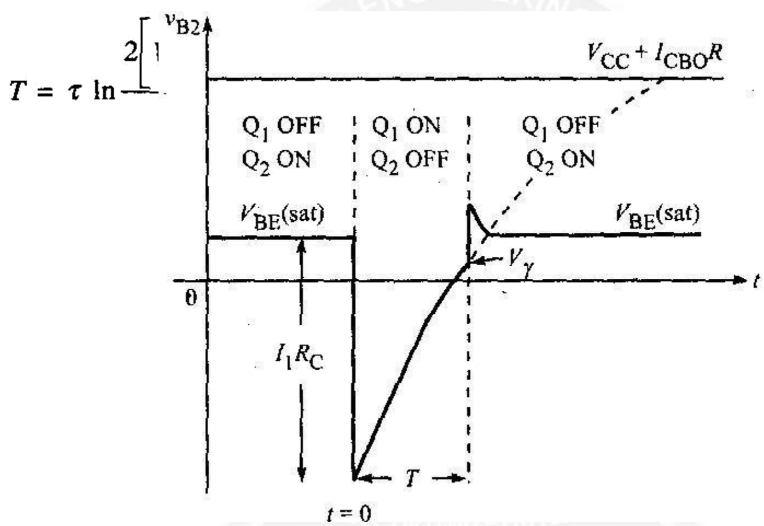

Figure 4.42(b) Voltage variation at the base of Q2 during the quasirstable state

So, the expression for the voltage at the base of Q_2 is given by

$$v_{B2} = (V_{CC} + I_{CBO}R) - [(V_{CC} + I_{CBO}R) - (V_{BE}(\text{sat}) - I_1R_C)]e^{-t/\tau}$$

$$= (V_{CC} + I_{CBO}R) - [(V_{CC} + I_{CBO}R) - (V_{BE}(\text{sat}) - (V_{CC} - V_{CE}(\text{sat}))]e^{-t/\tau}$$

At $t = T,\ v_{B2} = V_\gamma$

$$\therefore \quad V_\gamma = V_{CC} + I_{CBO}R - [2V_{CC} + I_{CBO}R - (V_{CE}(\text{sat}) + V_{BE}(\text{sat}))]e^{-T/\tau}$$

$$\therefore \quad e^{T/\tau} = \frac{2V_{CC} + I_{CBO}R - (V_{CE}(\text{sat}) + V_{BE}(\text{sat}))}{V_{CC} + I_{CBO}R - V_\gamma}$$

(considering

Neglecting the junction voltages and the cut-in voltage of the transistor,

$$T = \tau \ln \frac{2\left[V_{CC} + \frac{I_{CBO}R}{2}\right]}{V_{CC} + I_{CBO}R}$$

$$= \tau \ln 2 + \tau \ln \frac{1 + \frac{\phi}{2}}{1 + \phi}, \quad \text{where } \phi = \frac{I_{CBO}R}{V_{CC}}$$

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

- Since I_{CBO} increases with temperature, we can conclude that the delay time T decreases as temperature increases.

Waveforms of the collector-coupled monostable multivibrator

- The waveforms at the collectors and bases of both the transistors Q] and Q2 of the monostable multivibrator of Figure 4.41 are shown in Figure 4.44. The triggering signal is applied at t = 0, and the reverse transition occurs at t = T.

The stable state. For t < 0, the monostable circuit is in its stable state with Q_2 ON and Q, OFF. Since Q_2 is ON, the^ase voltage of Q_2 is $v_{B2} = V_{BE2}(sat)$ and the collector voltage of Q_2 is $v_{C2} = V_{CE2}(sat)$. Since Q, is OFF, there is no current in R_C of Q! and its base voltage must be negative. Hence the voltage at the collector of Q| is, $v_{C1} = V_{CC}$

and the voltage at the base of Q] using the superposition theorem is

$$v_{B1} = -V_{BB}\frac{R_1}{R_1 + R_2} + V_{CE2}(sat)\frac{R_2}{R_1 + R_2}$$

The quasi-stable state.

- A negative triggering signal applied at t = 0 brings Q_2 to OFF state and Qi to ON state.

A current /, flows in tf_C of Q]. So, the collector voltage of Qj drops suddenly by I_1R_C volts. Since the

voltage across the coupling capacitor C cannot change instantaneously, the voltage at the base of Q2 also drops by /itf$_C$, where I{R$_C$ = V$_{CC}$ -VcE2(^{sat})- Since Qi is ON,

$$v_{B1} = V_{BE1}(\text{sat}) \quad \text{and} \quad v_{C1} = V_{CE1}(\text{sat})$$

Also, $$v_{B2} = V_{BE2}(\text{sat}) - I_1R_C \quad \text{and} \quad v_{C2} = V_{CC}\frac{R_1}{R_1 + R_C} + V_{BE1}(\text{sat})\frac{R_C}{R_1 + R_C}$$

In the interval 0 < t < T, the voltages VGI, VBI and Vc2 remain constant at their values at f = 0, but the voltage at the base of. Q2, i.e. vB2 rises exponentially towards V$_{CC}$ with a time constant, t - RC, until at t

= T, vB2 reaches the cut-in voltage V$_X$ of the transistor.

Waveforms for t > T. At , reverse transition -takes place. Q2 conducts and Qi is cut-off. The collector voltage of Q2 and the base voltage of Qi return to their voltage levels for / < 0. The voltage vcl

now rises abruptly since Qt is OFF. This increase in voltage is transmitted to the base of Q2 and drives Q2 heavily into saturation. Hence an overshoot develops in vB2 at t = 7**", which decays as the capacitor recharges because of the base current. The magnitude of the base current may be calculated as follows.

Replace the input circuit of Q2 by the base spreading resistance rBB in series with the voltage VsE(sat) as shown in Figure 4.43. Let 7B be the base current at t = 1*. The current in R may be neglected compared to /'B.

From Figure 4.43,

$$V'_{BE} = I'_B r'_{BB} + V_{BE}(\text{sat}) \quad \text{and} \quad V_C = V_{CC} - I'_B R_C - V'_{BE}$$

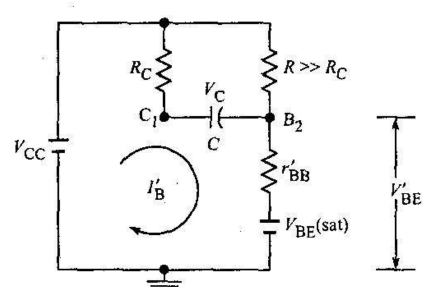

Figure 4.43 Equivalent circuit for calculating the overshoot at base 62 of Q3.

The jumps in voltages at B2 and C| are, respectively, given by

$$\delta = V'_{BE} - V_\gamma = I'_B r'_{BB} + V_{BE}(\text{sat}) - V_\gamma \quad \text{and} \quad \delta' = V_{CC} - V_{CE}(\text{sat}) - I'_B R_C$$

Since C] and B2 are connected by a capacitor C and since the voltage across the capacitts cannotchange instantaneously, these two discontinuous voltage changes 5 and 5' must bl equal.

Equating them,

$$I'_B r'_{BB} + V_{BE}(\text{sat}) - V_\gamma = V_{CC} - V_{CE}(\text{sat}) - I'_B R_C$$

$$I'_B = \frac{V_{CC} - V_{BE}(\text{sat}) - V_{CE}(\text{sat}) + V_\gamma}{R_C + r'_{BB}}$$

vB2 and vcl decay to their steady-state values with a time constant $\tau' = (R_C + r'_{BB})C$