BJT DC Analysis: (n-p-n)

(i) Assume BJT is in forward active mode

$V_{BE} = V_{BE(ON)} \approx 0.7\,V$ for Silicon BJT

$I_B > 0$ and $I_C = \beta I_B$

(ii) Analyze the 'linear' circuit.

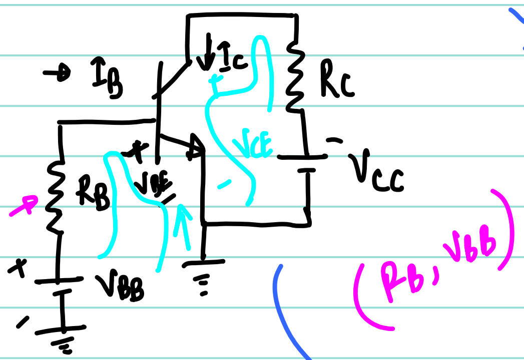
(iii) If $V_{CE} > V_{CE(sat)}$ → then active region (our assumption is correct)

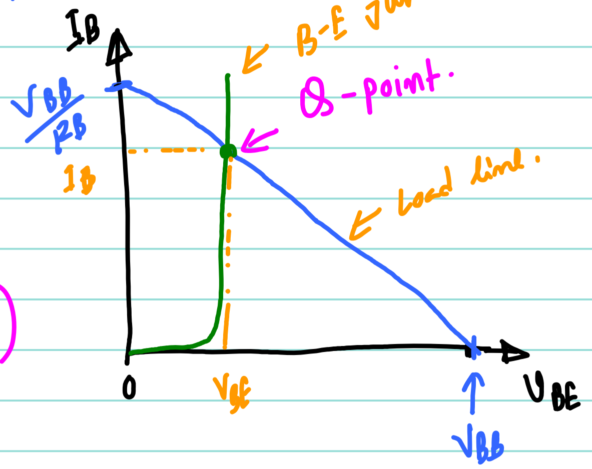
- if $V_{CE} < 0$ → Probably, BJT is in saturation
- if $I_B < 0$ → Probably BJT is in Cut-off

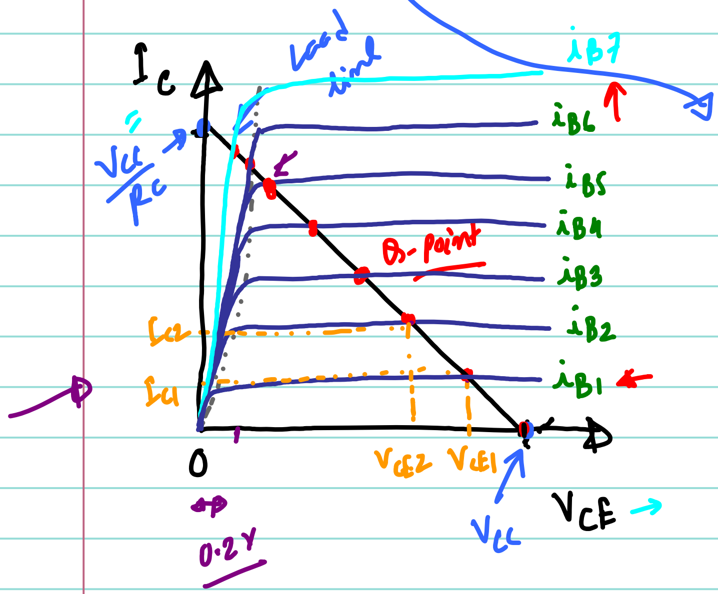
Lec-14

Load line:

$V_{BB} = I_B R_B + V_{BE}$, $I_B = \frac{V_{BB}}{R_B} - \frac{V_{BE}}{R_B}$

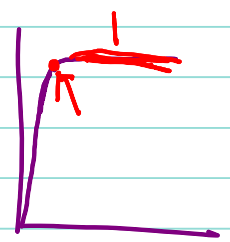




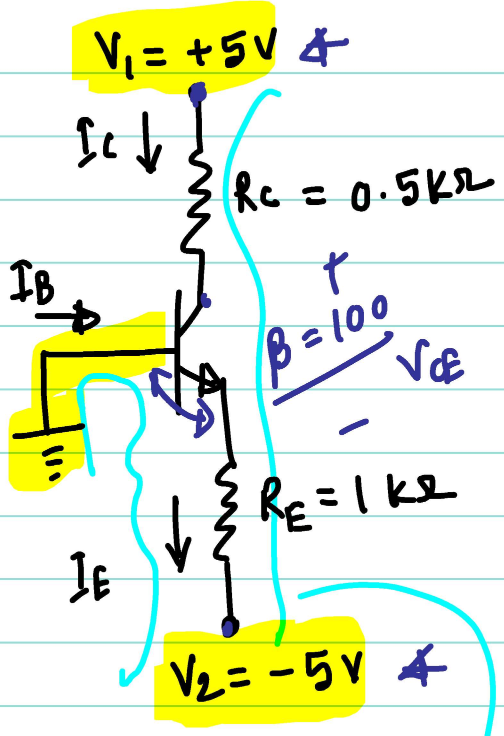


$V_{CC} = I_C R_C + V_{CE}$

$I_C = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C}$



Example



Find Q-point

$$0 = \overset{0.65V}{V_{BE.ON}} + I_E R_E - 5$$

$$I_E = 4.35\ mA.$$

$$I_C = \alpha I_E$$

$$\beta = 100, \quad \alpha = \frac{100}{101} = 0.99$$

$$I_C = 0.99 \times I_E$$

$$I_C = 4.307\ mA. \quad (Q.)$$

V_{CE} ??

$$-V_1 + I_C R_C + V_{CE} + I_E R_E + V_2 = 0$$

$$V_{CE} = 3.5\ V \quad (Q)$$

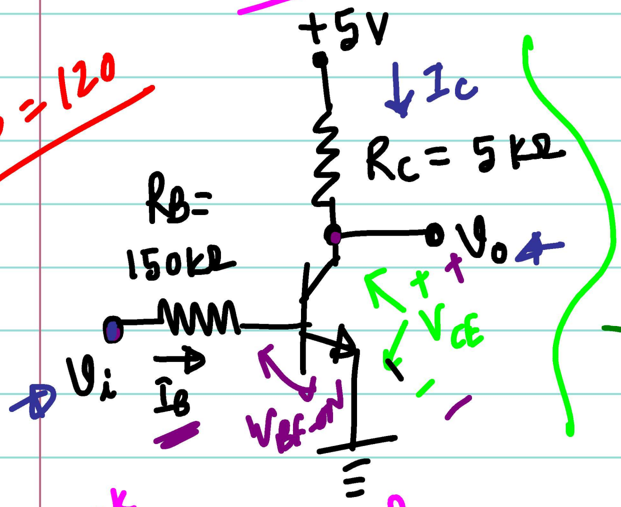
$5 = I_C R_C + V_{CE}$

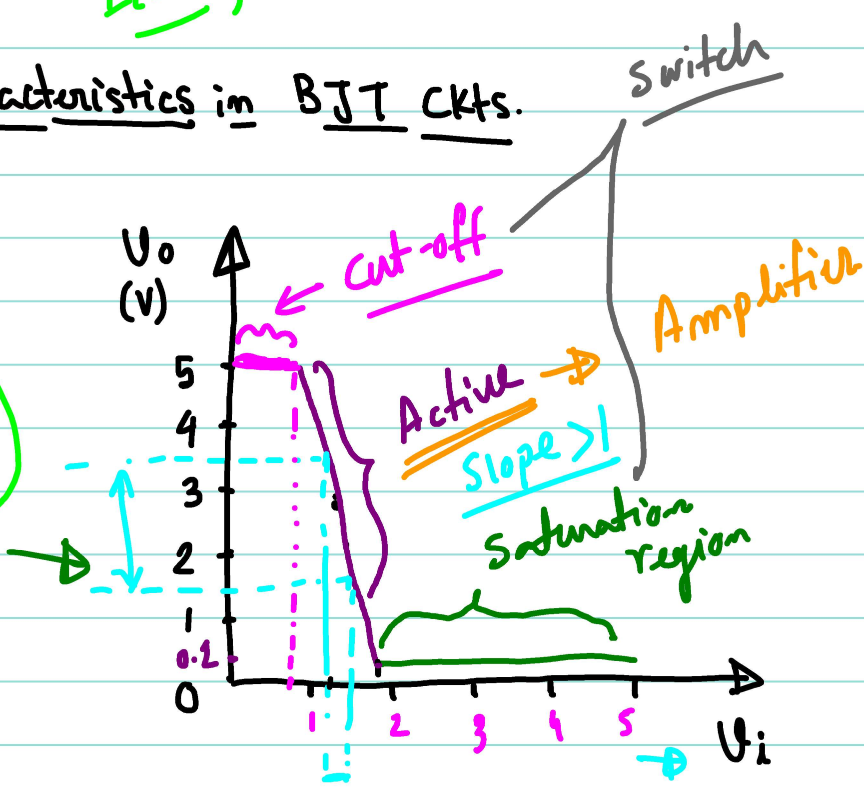
$I_C = 0$, $V_{CE} = 5V$

Voltage Transfer Characteristics in BJT ckts.

VTC

$\beta = 120$





Homework using p-n-p.

(i) $V_i \to 0$, $V_i < 0.7V$, cut-off. $I_C = I_B = 0$

$V_o = 5V$

(ii) $V_i > 0.7V$, BJT is in forward Active mode,

$$\rightarrow I_B = \frac{V_i - V_{BE-ON}}{R_B} \; ; \; I_C = \beta \cdot I_B$$

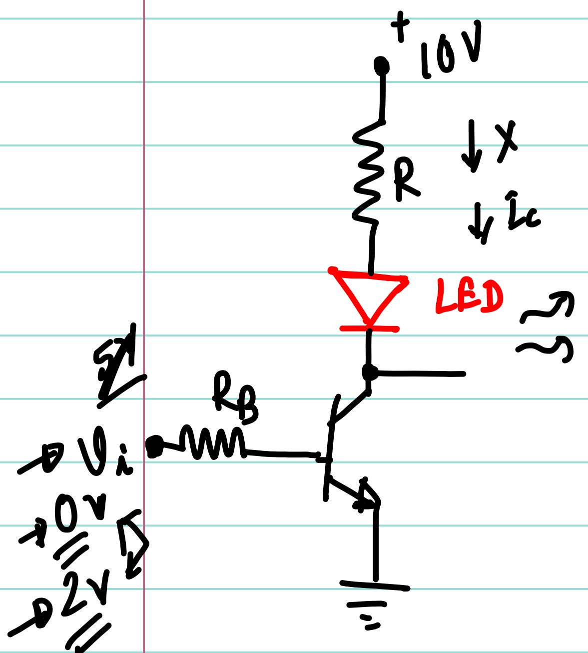
$$I_C = \beta \cdot \frac{V_i - V_{BE-ON}}{R_B}$$

$$\rightarrow V_o = 5 - I_C R_C = 5 - \beta \cdot R_C \cdot \frac{V_i - V_{BE \cdot ON}}{R_B}$$

$$0.2 = 5 - \beta R_C \cdot \frac{V_i - V_{BE-ON}}{R_B} \; ; \; V_i = 1.9V$$

(iii) $V_i > 1.9V$, $V_o = V_{CE\text{-}sat} = 0.2V$.

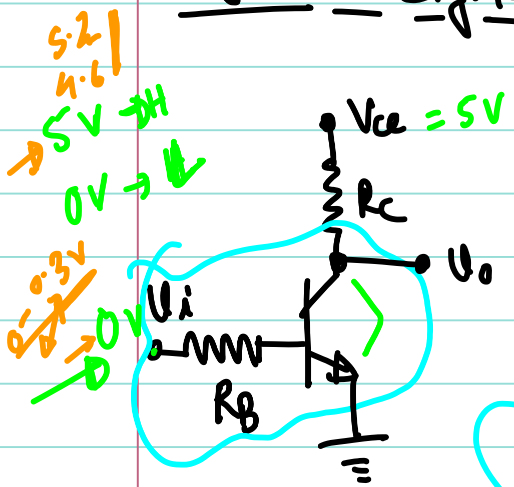
BJT as switch:

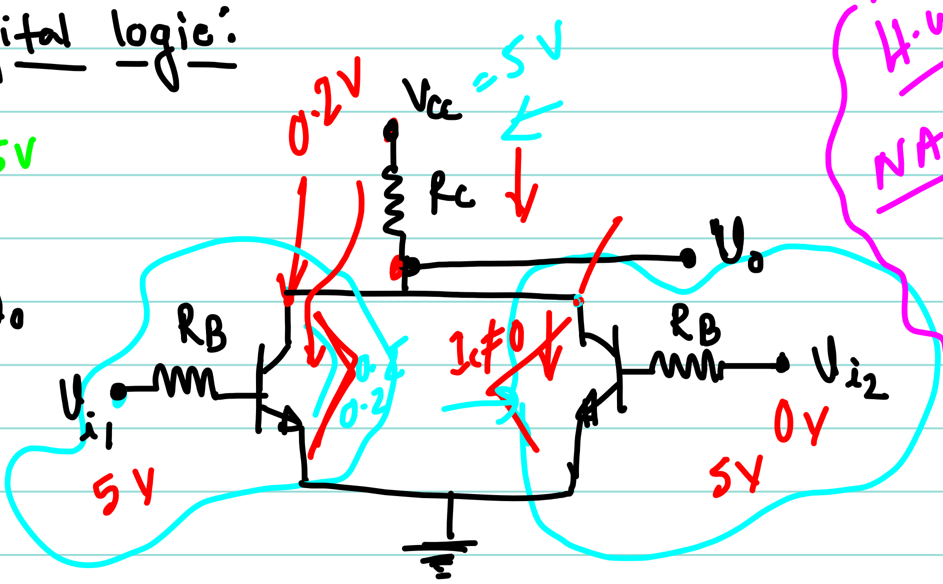


Saturation

Cut-off

BJT as digital logic:





H.W.
NAND
AND
OR

Input	output
0V (0)	5V (1)
5V (1)	0.2V (0)

↓

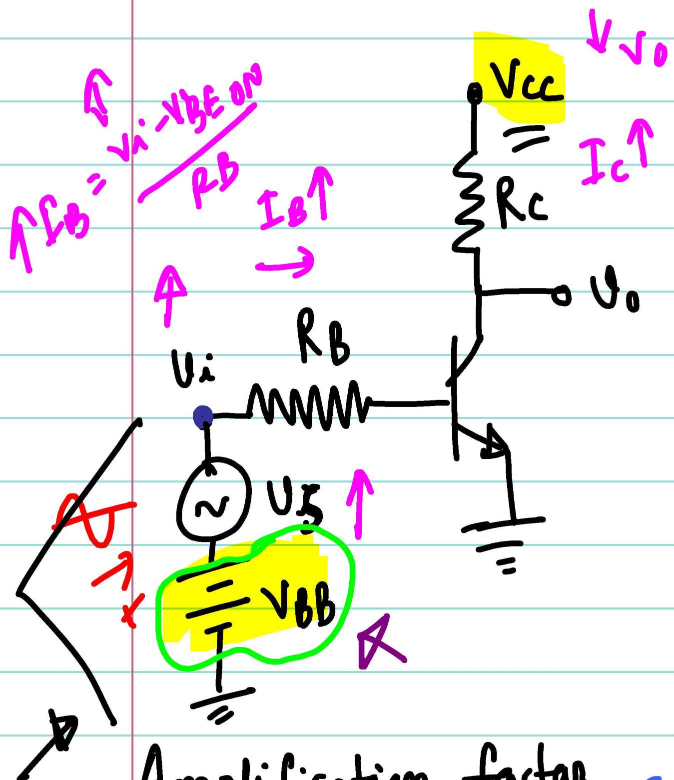
NOT / Inverter

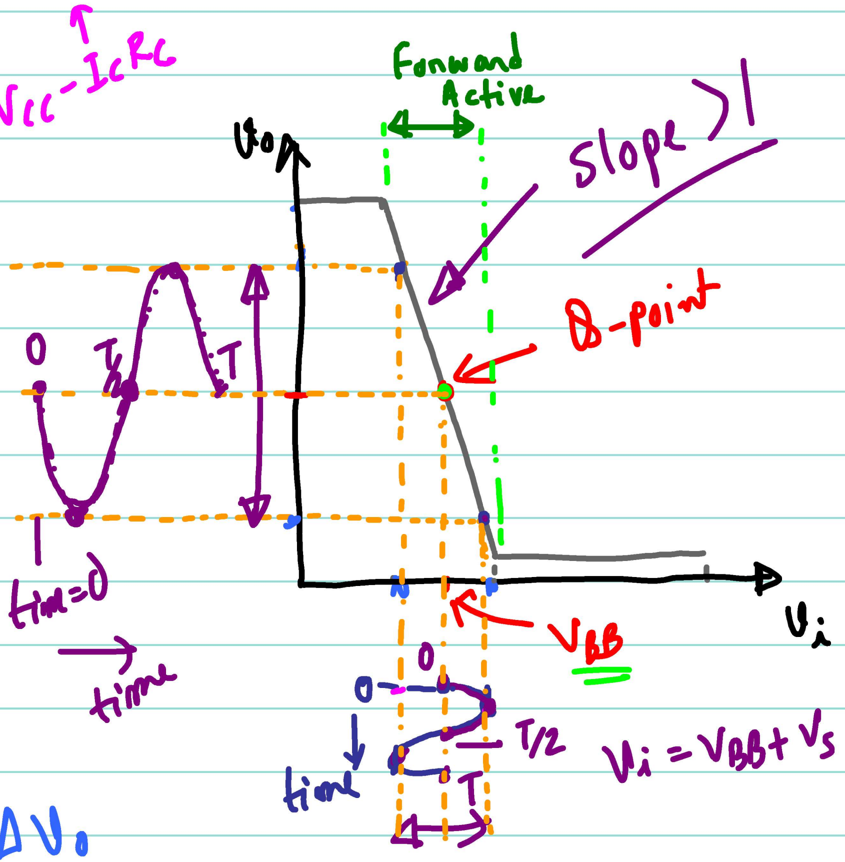
logic

Inputs V_{i_1}	Inputs V_{i_2}		output V_o
0V (0)	0V (0)	→	5V (1)
5V (1)	0V (0)	→	0.2V (0)
0V (0)	5V (1)	→	0.2V (0)
5V (1)	5V (1)	→	0.2V (0)

NOR

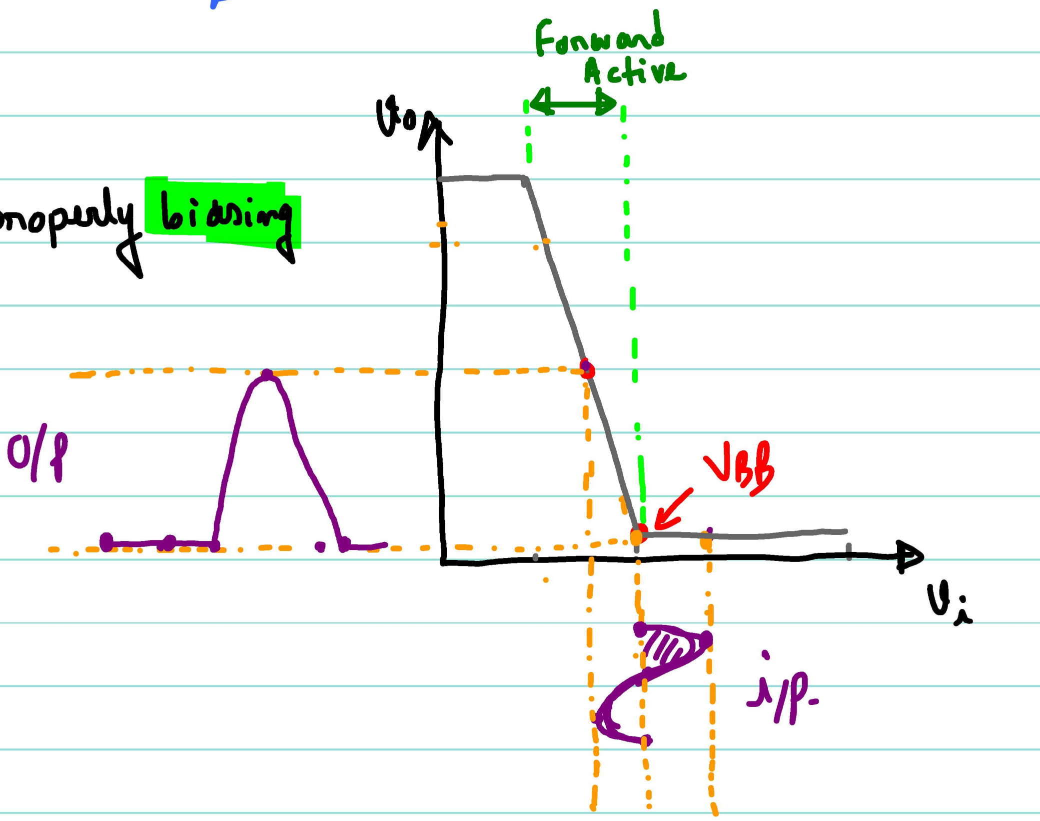
BJT as amplifier:





Amplification factor $= \frac{\Delta V_o}{\Delta V_i}$ in forward Active mode

▷ **Importance of properly biasing** a transistor



Biasing of BJT:

(1) Biasing using a single resistan

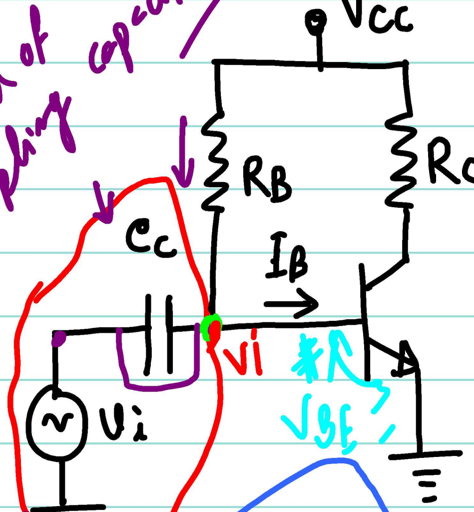
$\downarrow\downarrow X_C = \frac{1}{\omega C \uparrow}$

typical value $\boxed{C_C \Rightarrow \mu F}$

Value of coupling capaciton.

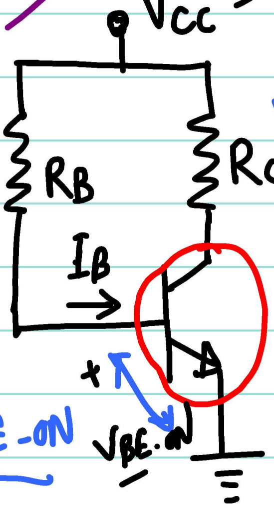
freq: of input signal

$\omega\downarrow$



$\boxed{I_{CQ} \propto \beta}$

DC analysis



$\downarrow I_{BQ}$

$\beta = 300$

$\beta = 200$

$$I_{BQ} = \frac{V_{CC} - V_{BE\text{-}ON}}{R_B}$$

$$I_{CQ} = \beta \cdot I_{BQ} = \beta \cdot \frac{V_{CC} - V_{BE\,ON}}{R_B}.$$

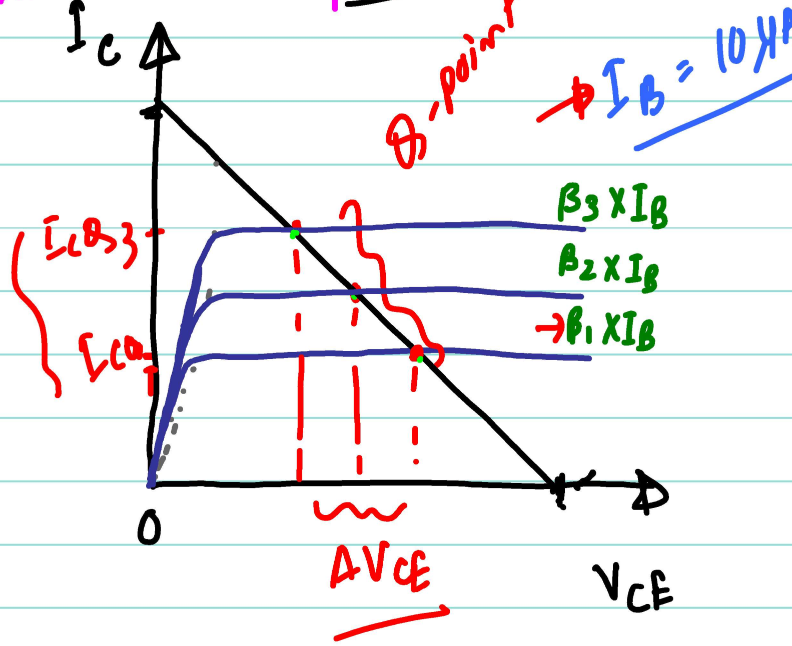
Value of R_B: typical value of $I_B \rightarrow \mu A$ $(10\,\mu A)$

Required.
$$R_B = \frac{V_{CC} - V_{BE\text{-}ON}}{I_B} = 113 \times 10^4\ \Omega$$

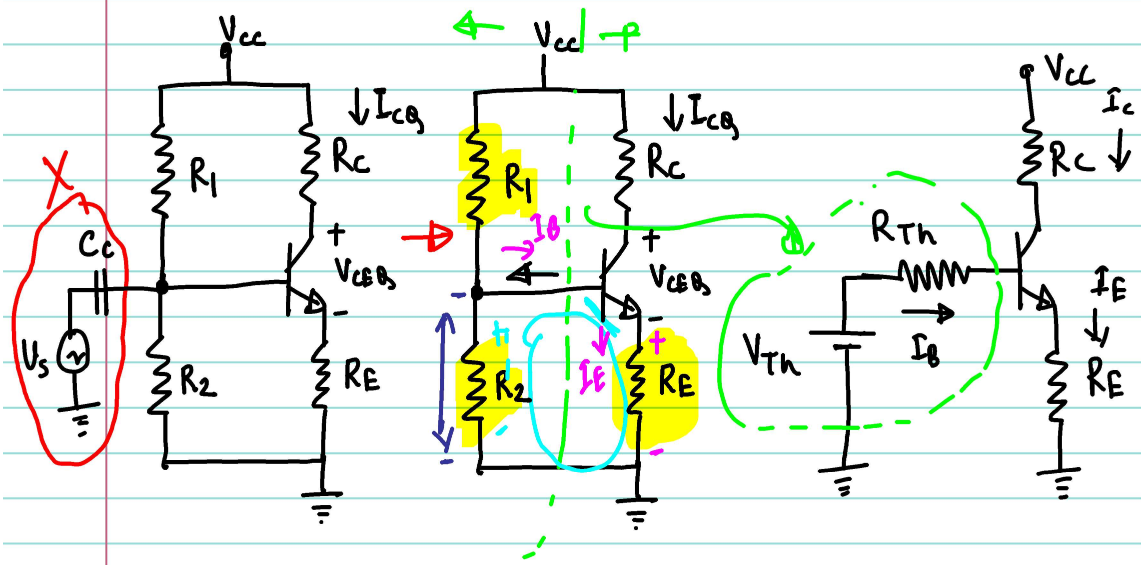
$$\boxed{R_B = 1.13\ M\Omega}$$

very high value difficult to implement in IC

Stability of Q-point: due to change in 'β'



(ii) Voltage divider biasing with emitter resistor:



$$V_{Th} = V_{CC} \cdot \frac{R_2}{R_1 + R_2} \quad ; \quad R_{Th} = R_1 \parallel R_2$$

$$V_{Th} = I_B \cdot R_{Th} + V_{BE\,ON} + I_E R_E \quad ; \quad I_E = (1+\beta) I_B$$

$$V_{Th} = I_B \cdot R_{Th} + V_{BE\,ON} + (1+\beta) I_B R_E .$$

$$I_B = \frac{V_{Th} - V_{BE\text{-}ON}}{R_{Th} + (1+\beta) R_E} \quad ; \quad I_C = \beta I_B$$

$$I_C = \beta \times \frac{V_{Th} - V_{BE\,ON}}{R_{Th} + (1+\beta) R_E}$$

$$R_{Th} \ll (1+\beta) R_E$$

$$I_C \approx \frac{\beta (V_{Th} - V_{BE\,ON})}{\cancel{(1+\beta)} R_E} \quad ; \quad \beta \gg 1, \quad 1+\beta \approx \beta$$

$$I_C \approx \frac{V_{Th} - V_{BE\,ON}}{R_E}$$

; I_C is independent of 'β'