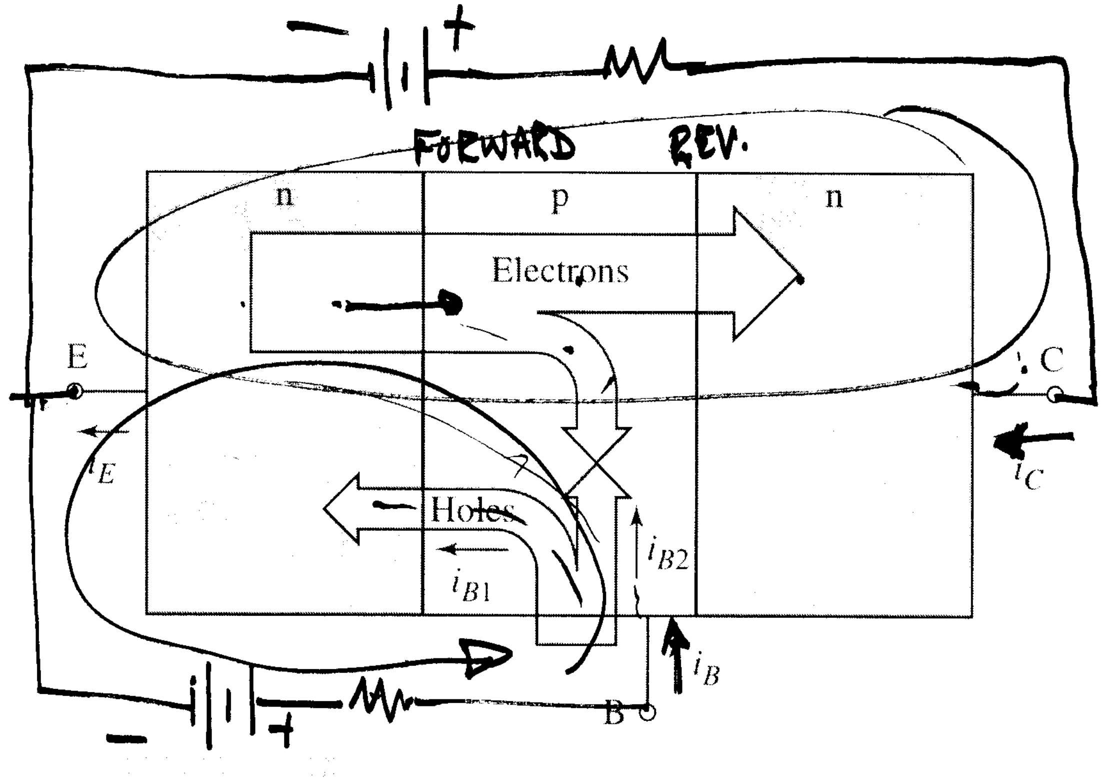
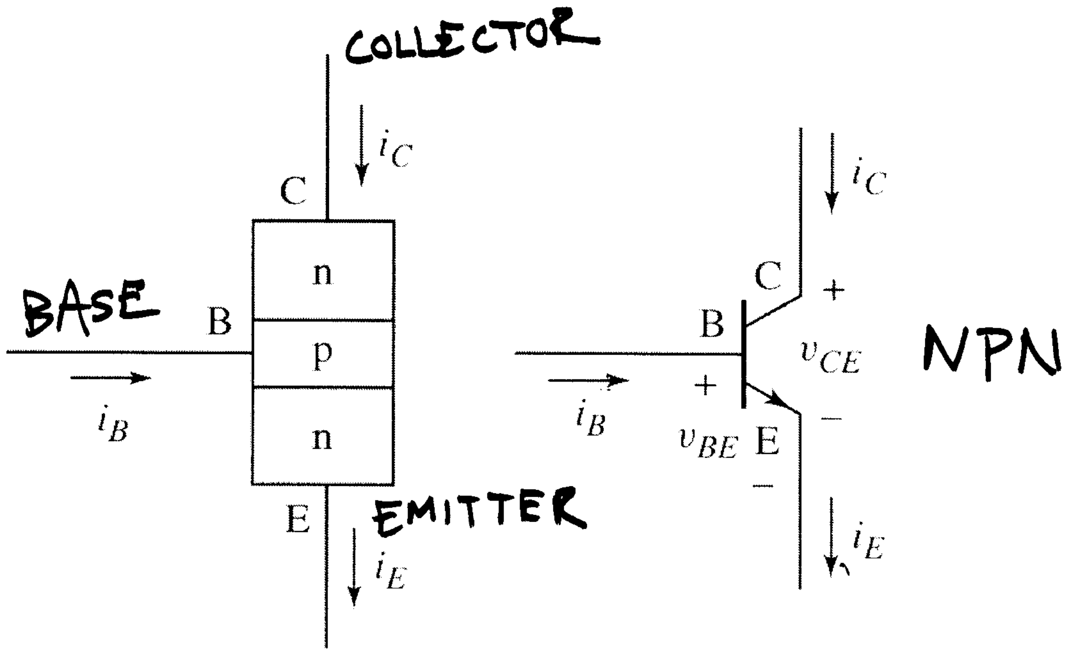


FORWARD
REV.
n
p
n
Electrons
Holes
E
C
B
iE
iC
iB1
iB2
iB



COLLECTOR
BASE
EMITTER
C
B
E
n
p
n
iC
iB
iE
vCE
vBE
NPN

(a)

(b)

$$I_s\left(e^{v_{BE}/V_T}-1\right)$$

$$i_C \cong I_S e^{v_{BE}/V_T}$$

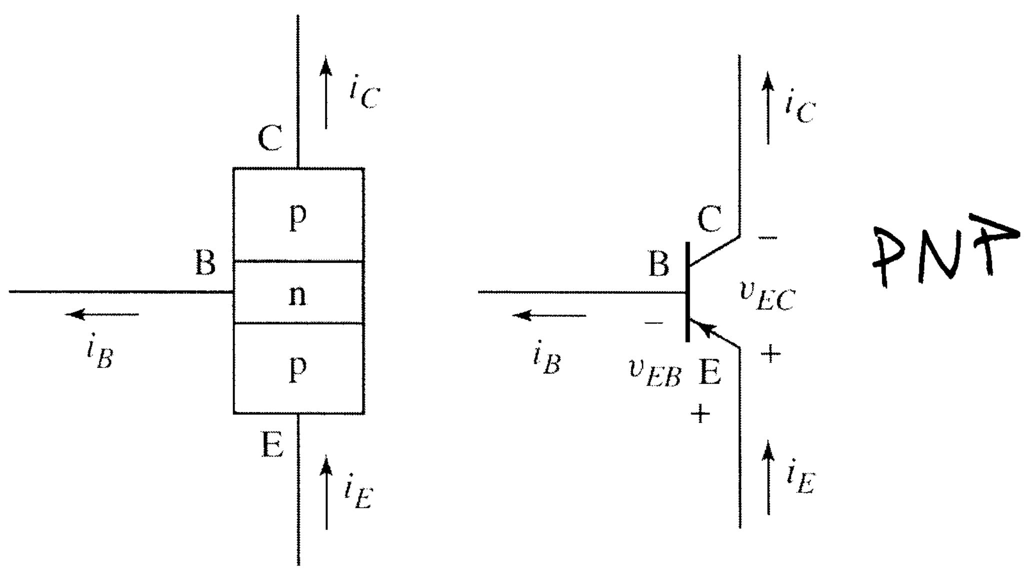
$$i_E = i_C + i_B \quad \text{(KCL)}$$

$$\boxed{i_C = \beta i_B}$$

$$i_E = (1+\beta i_B)$$

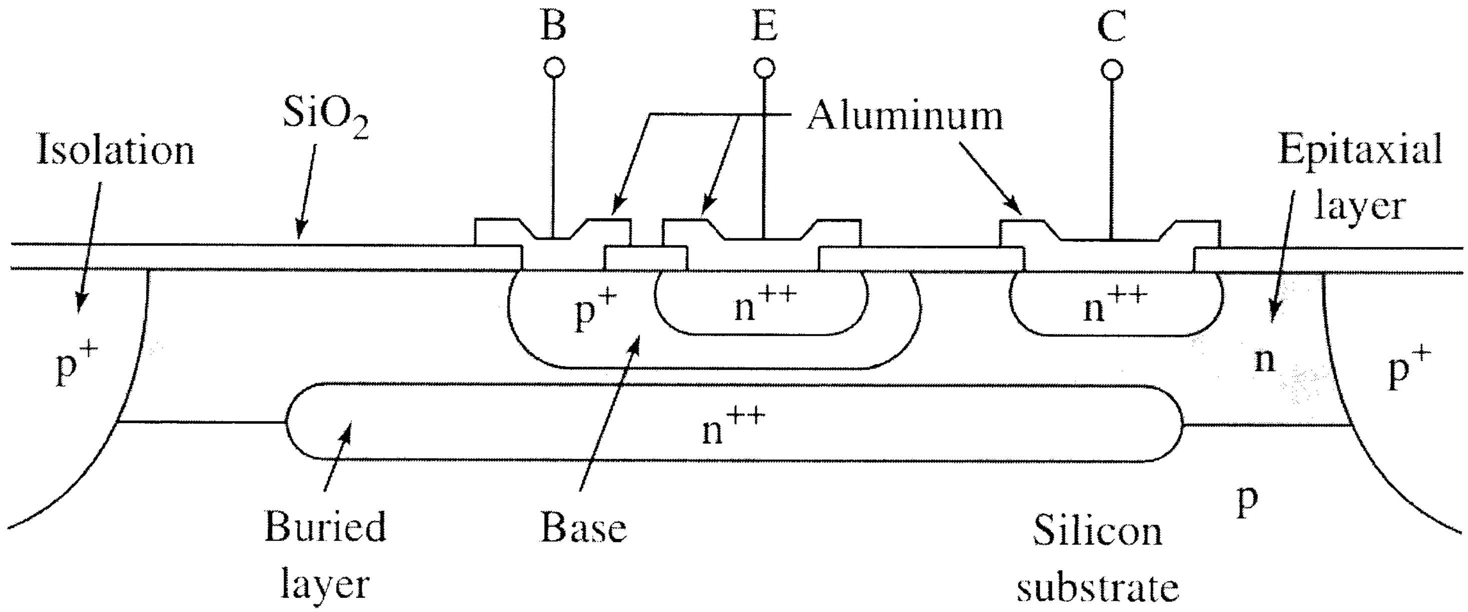
$$i_C = \alpha i_E$$

$$\beta = \frac{\alpha}{1-\alpha} \qquad \alpha = \frac{\beta}{1+\beta}$$

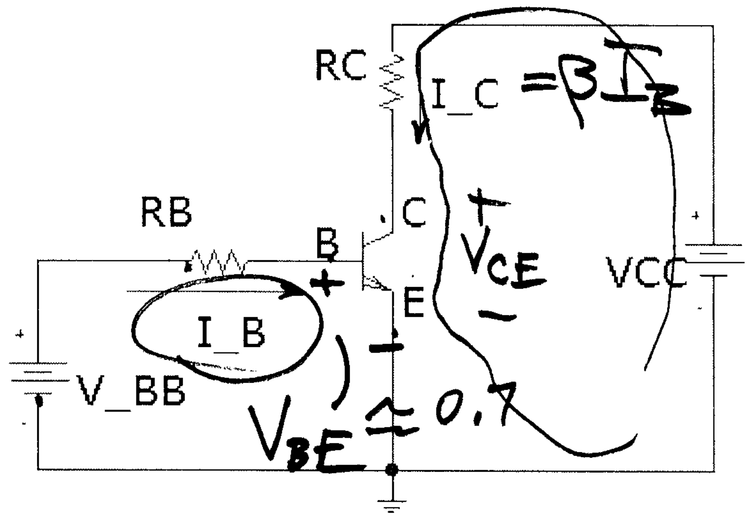


(a) (b)

Cross Section of Integrated Circuit npn Transistor



ANALYSIS OF THE DC BIAS CIRCUIT



KVL on the base side:

$$-V_{BB} + I_B R_B + V_{BE} = 0$$

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

$$I_B = \frac{V_{BB} - 0.7}{R_B}$$

KVL on the collector side:

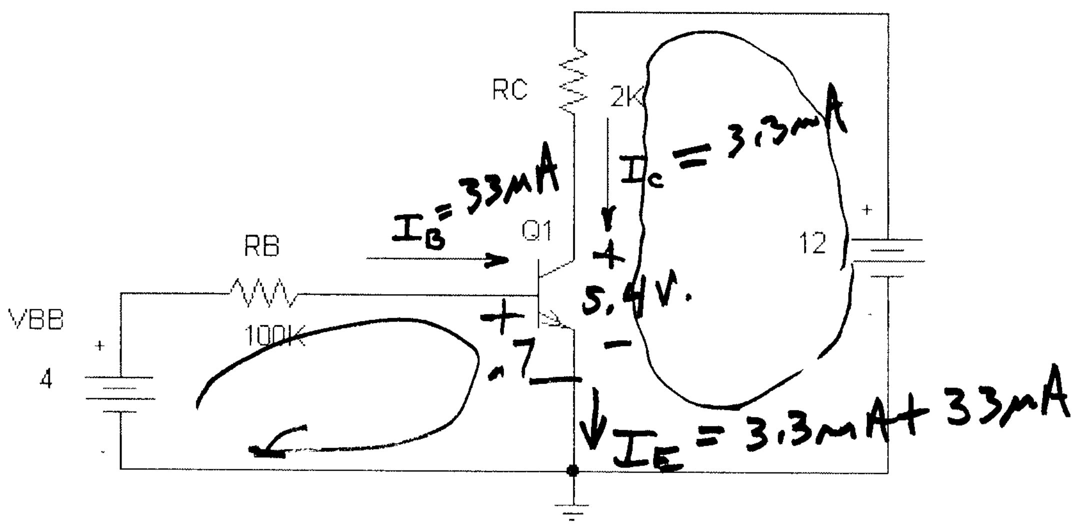
$$-V_{CC} + I_C R_C + V_{CE} = 0$$

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

$$\boxed{I_C = \beta I_B}$$

Example:

β = 100

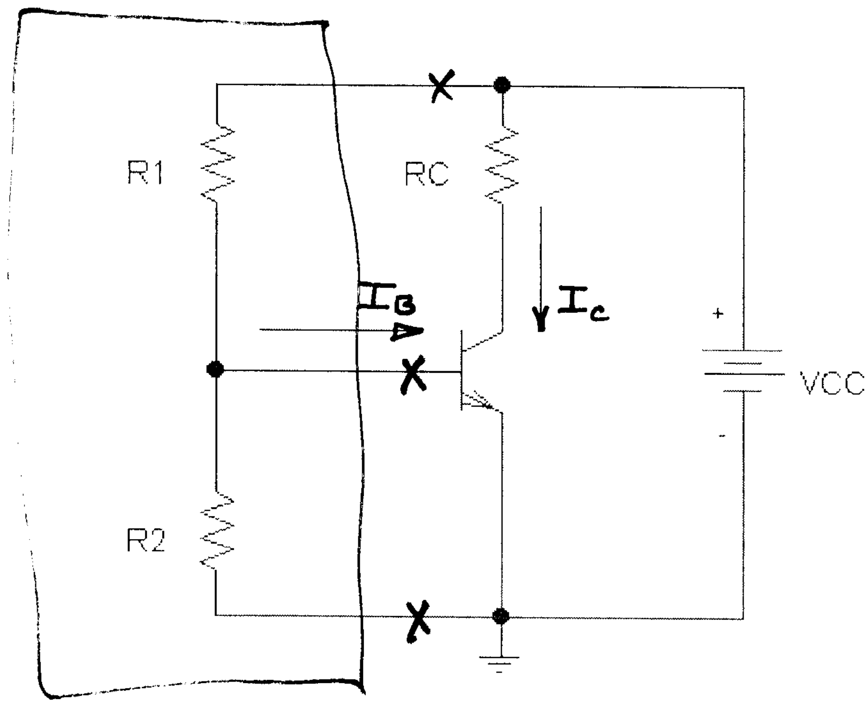


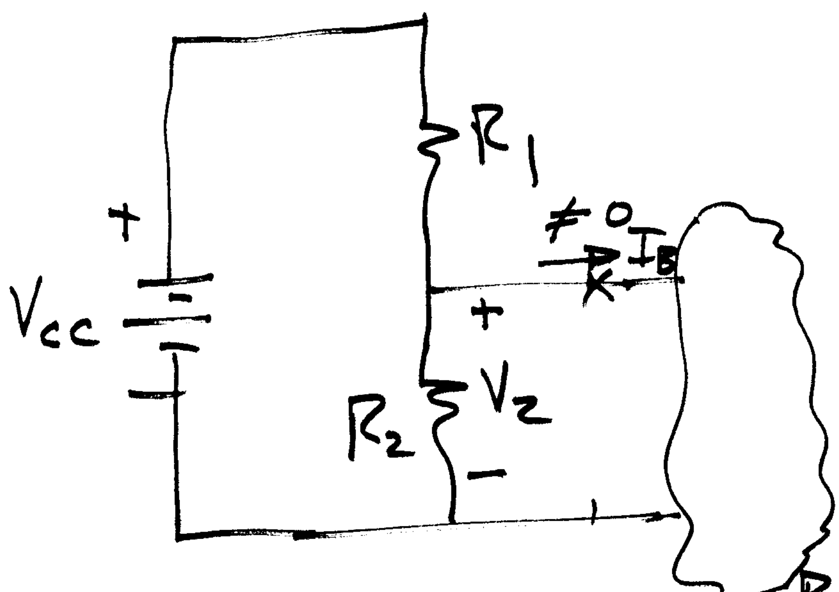
$$I_B = \frac{V_{BB} - 0.7}{R_B} = \frac{4 - 0.7}{100k} = 33\ \mu A$$

$$I_C = \beta I_B = 100(33\ \mu A) = 3.3\ mA$$

$$V_{CE} = V_{CC} - I_C R_C = 12 - (3.3)(2) = 5.4\ V.$$

BJT BIASING WITH A SINGLE DC SOURCE

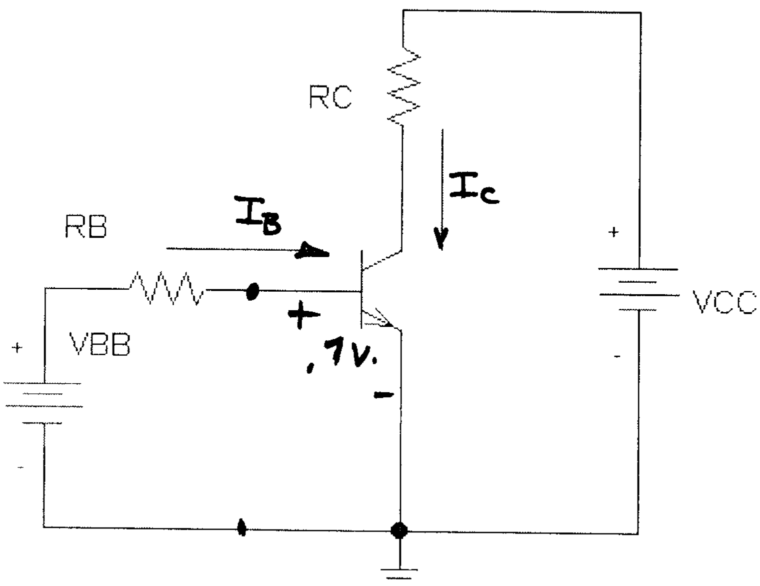


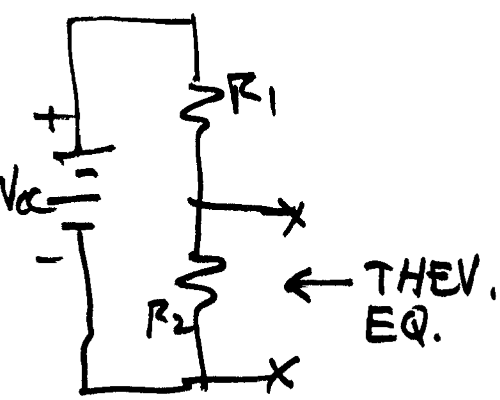


$$V_2 \neq V_{cc}\left[\frac{R_2}{R_1+R_2}\right]$$

because $I_B \neq 0$

Thevenin Equivalent on the Base Side:

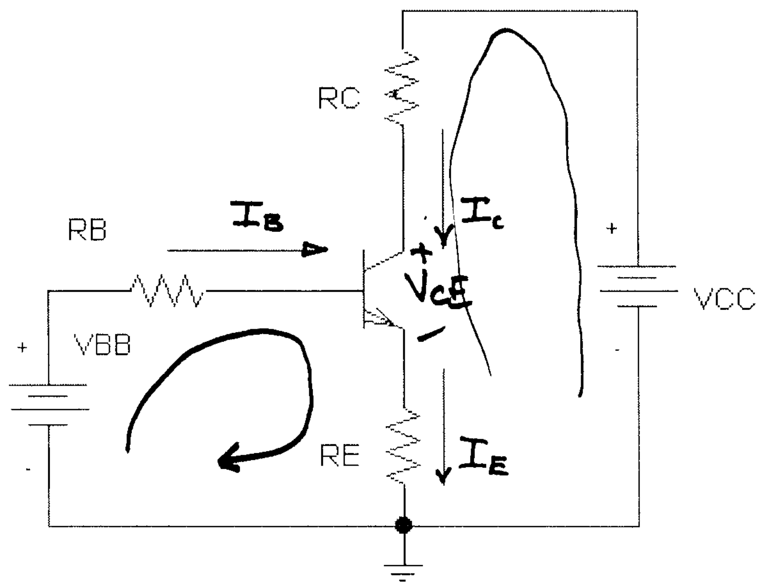




$$V_{BB} = V_{th} = V_{CC}\left(\frac{R_2}{R_1 + R_2}\right)$$

$$R_B = R_{th} = \left(\frac{R_1 \; R_2}{R_1 + R_2}\right)$$

Biasing with R_E



KVL on the base side:

$$-V_{BB} + I_B R_B + \overset{0.7V.}{V_{BE}} + I_E R_E = 0$$

$$I_E = I_C + I_B = I_B(\beta + 1)$$

$$I_C = \beta I_B$$

$$-V_{BB} + I_B R_B + V_{BE} + I_B(\beta + 1) R_E = 0$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + (\beta + 1) R_E}$$

$I_C = \beta I_B$

KVL

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

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

Why do we include R_E?

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + (\beta + 1) R_E}$$

$R_E = 0$

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

$I_C = \beta I_B$

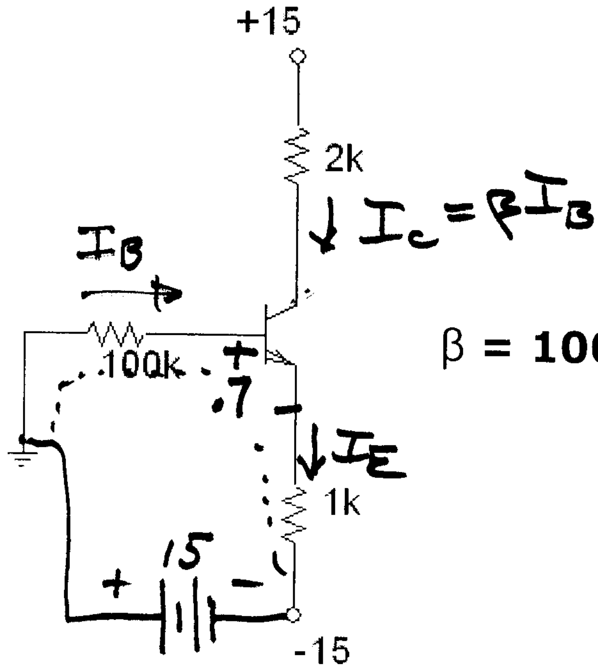
$$I_C = \beta I_B = \beta \left(\frac{V_{BB} - V_{BE}}{R_B + \underbrace{(\beta + 1) R_E}} \right)$$

If we make $(\beta + 1)R_E >> R_B$,

$$I_C = \beta \left(\frac{V_{BB} - V_{BE}}{R_B + (\beta + 1) R_E} \right) \approx \beta \left(\frac{V_{BB} - V_{BE}}{(\beta + 1) R_E} \right)$$

$$I_C = \left(\frac{V_{BB} - V_{BE}}{R_E} \right) \left[\left(\frac{\beta}{\beta + 1} \right) \right] \approx \frac{V_{BB} - V_{BE}}{R_E}$$

$\therefore$ **I_C is nearly independent of β.**



β = **100**

(1) SOLVE FOR I_B

$$100K\,I_B + 0.7 + I_E(1K) - 15 = 0$$

$$I_B = \frac{I_E}{\beta+1}$$

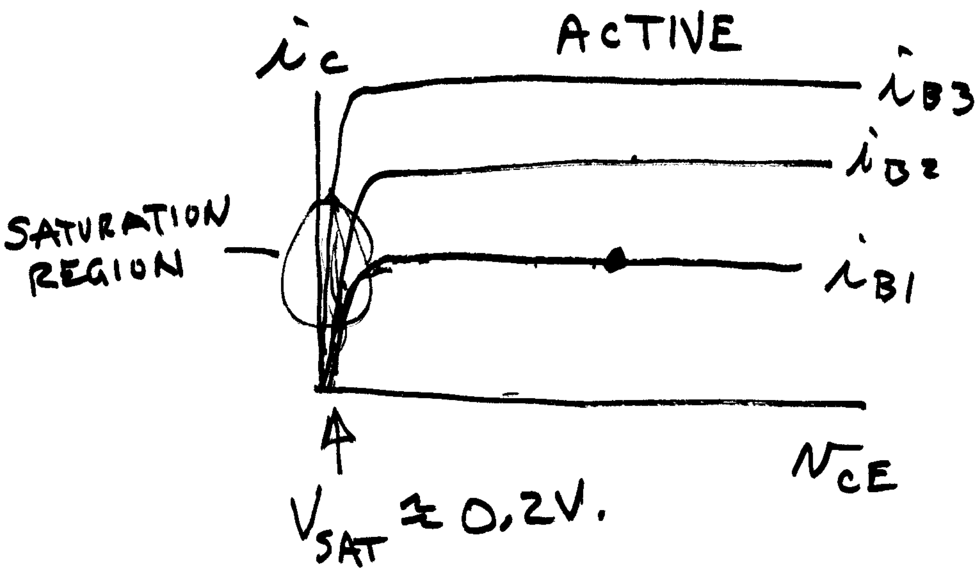
$$\left[\frac{I_E}{\beta+1}\right]100K + I_E(1K) = 14.3$$

$$I_E = 7.19\,mA$$

$$I_B = \frac{I_E}{\beta+1} = 71.1\,\mu A$$

$$I_C = \beta I_B = 7.11\,mA$$

$$V_{CE} = 30 - I_C(2K) - I_E(1K) = 8.58V.$$



ACTIVE
ic
iB3
iB2
iB1
SATURATION REGION
vCE
VSAT ≈ 0.2V.