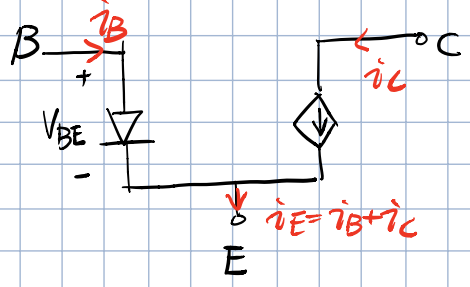
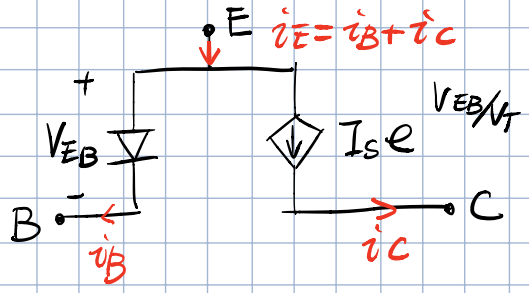
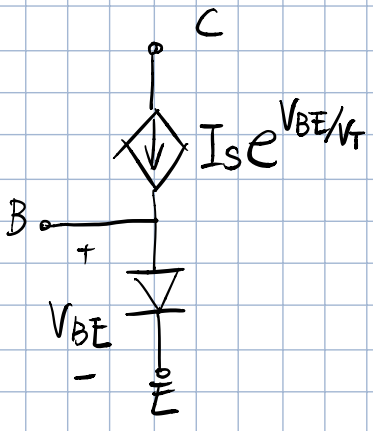




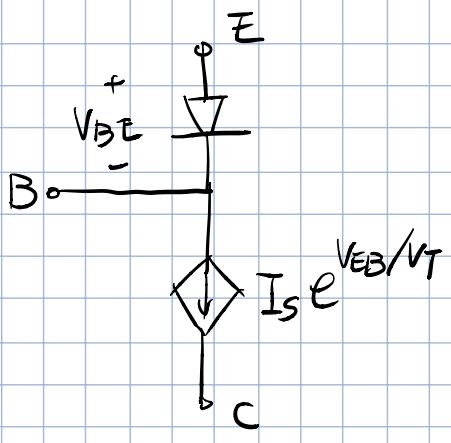
npn BJT **hybrid-π model**

npn BJT

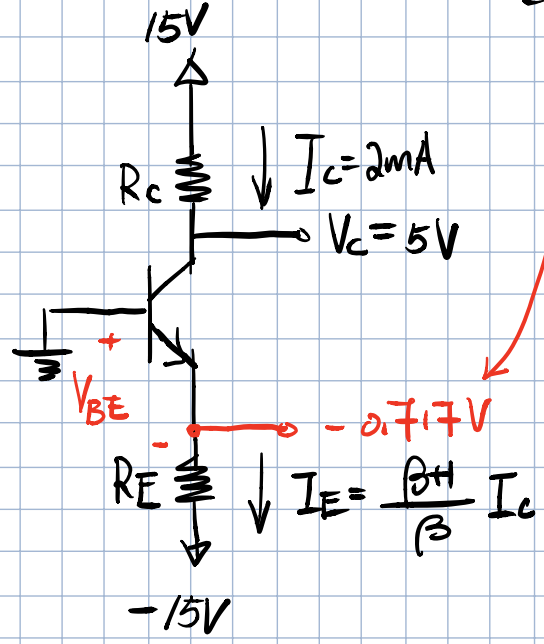


T-model

pnp BJT



Example 1 npn $\beta = 100$, $V_{BE} = 0.7V$ @ 1mA (i_C), design a ckt so that $I_C = 2mA$ and $V_C = 5V$



$$V_{BE} = 0.7V + V_T \ln\left(\frac{2mA}{1mA}\right) = 0.717V$$

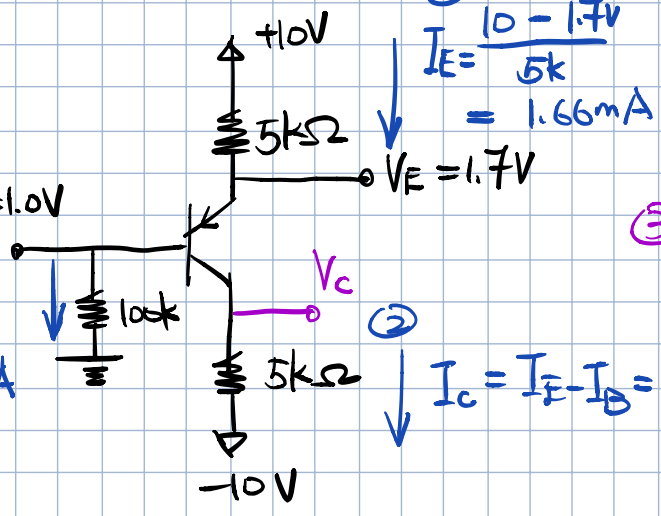
$$R_C = \frac{15 - V_C}{I_C} = \frac{15 - 5V}{2mA} = 5k\Omega$$

$$R_E = \frac{-0.717 - (-15)}{I_E} = \frac{-0.717 + 15}{\frac{100+1}{100} \times I_C}$$

$$= 7.07k\Omega$$

Example 2 pnp, $V_B = 1.0V$, $V_E = 1.7V$, find α, β and V_C

assume active mode.



$I_E = \frac{10 - 1.7V}{5k} = 1.66mA$

① $I_B = \frac{V_B}{10k} = 0.01mA$

② $I_C = I_E - I_B = 1.65mA$

③ $V_C = -10 + 5k \times I_C = -1.75V$

check $V_{EC} = 1.7V - (-1.75V) = 3.45V > 0.3V$ (or $0.2V$)

⇒ Yes, the transistor is in active mode.

$$\beta = I_C / I_B = \frac{1.65}{0.01} = 165, \quad \alpha = \frac{\beta}{\beta+1} = 0.994$$

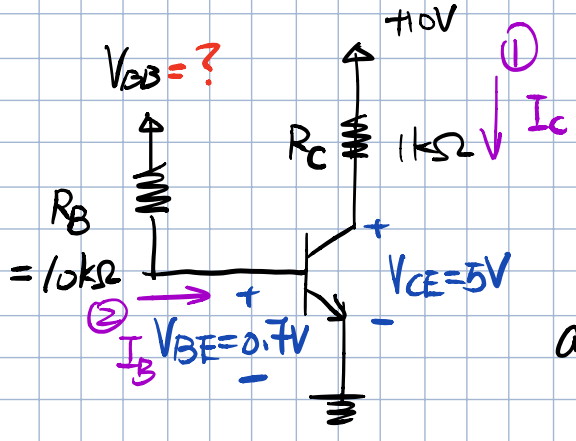
Example 3

Determine V_{BB} for

a) In the active mode $V_{CE} = 5V$

b) In the saturation $\beta_{force} = 10$

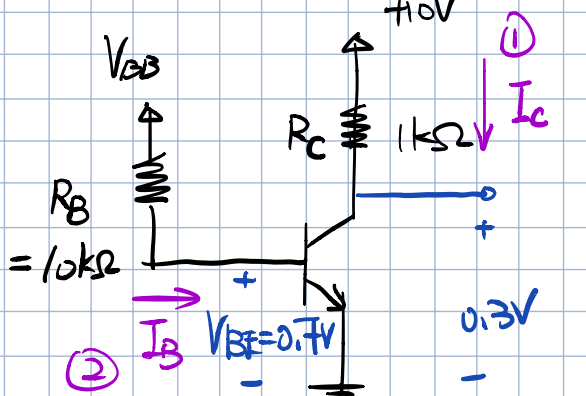
assume $V_{BE} = 0.7V$ and $\beta = 50$ in active.



a) $I_C = \frac{10-5}{1k} = 5mA$

$I_B = I_C / \beta = \frac{5mA}{50} = 0.1mA$

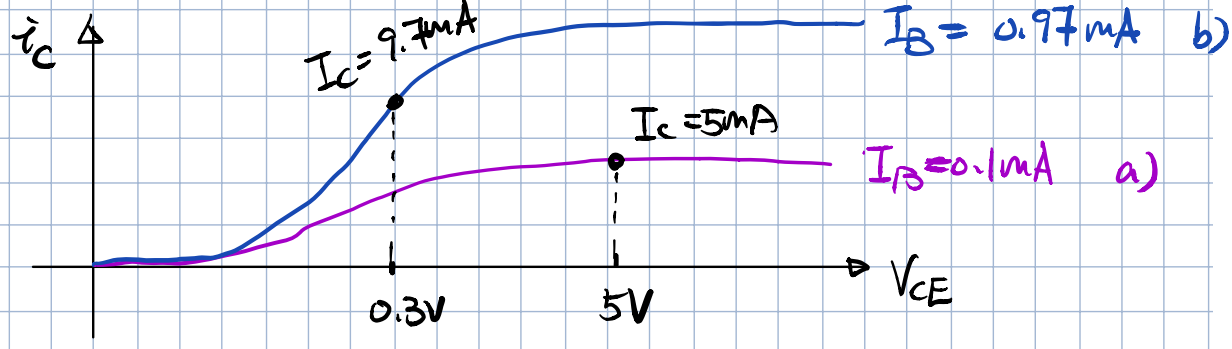
$V_{BB} = 0.7V + 10k\Omega (0.1mA) = 1.7V$



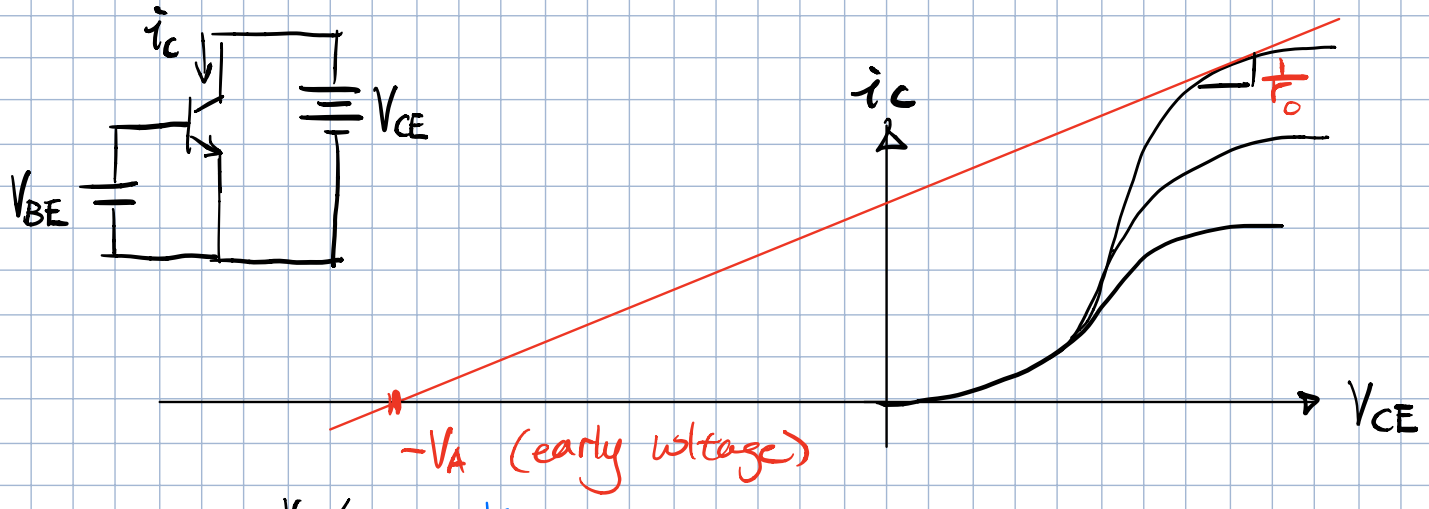
b) $I_C = \frac{10 - 0.3}{1k} = 9.7mA$

$I_B = I_C / \beta_{force} = 0.97mA$

$V_{BB} = V_{BE} + R_B I_B = 10.4V$



The early effect.



$$i_C = I_S e^{V_{BE}/V_T}\left(1 + \frac{V_{CE}}{V_A}\right)$$

I_C without early effect.

$$\frac{1}{r_o} = \left.\frac{di_C}{dV_{CE}}\right|_{V_{CE}=\text{const.}} = I_S e^{V_{BE}/V_T} \cdot \frac{1}{V_A} = \frac{I_C}{V_A}$$

$$\boxed{r_o = \frac{V_A}{I_C}}$$