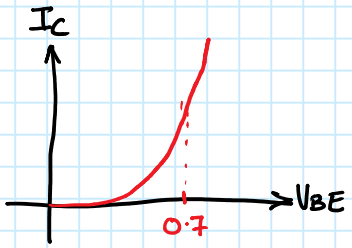
Lecture 21

BJT I/V characteristics:

$$I_C = I_S \cdot \exp\left(V_{BE}/V_T\right)$$

Typically $V_{BE} = 0.6 - 0.8\,V$

Assume $V_{BE} \approx 0.7\,V$



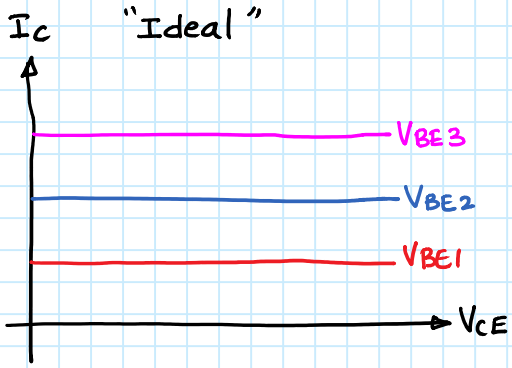
Example: $I_S = 5 \times 10^{-16}\,A$; $V_T = \frac{kT}{q} = 26\,mV$ @ room temperature

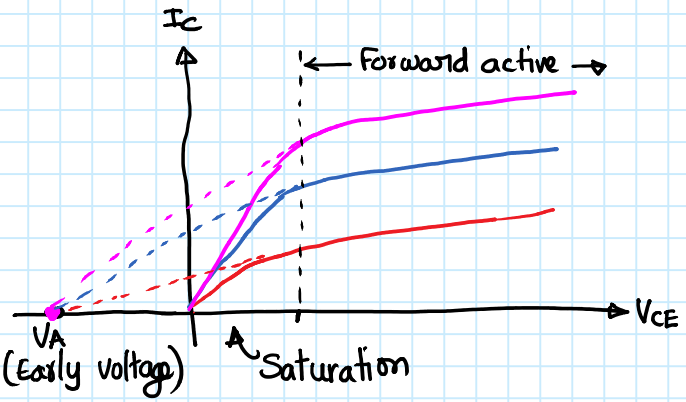
$V_{BE1} = 0.7 \Rightarrow I_C = 246\,\mu A$

$V_{BE2} = 0.75 \Rightarrow I_C = 1.69\,mA$

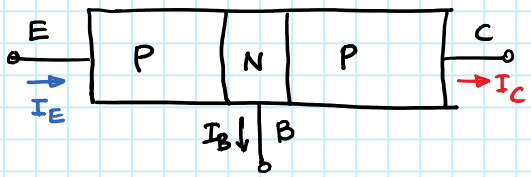
$V_{BE3} = 0.8 \Rightarrow I_C = 11.53\,mA$

I_C Vs V_{CE}





PNP BJT:

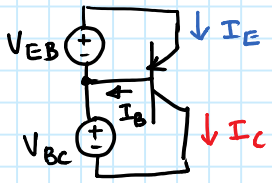


$I_E = I_B + I_C$

$I_C = I_S \exp\left(V_{EB}/V_T\right) = \alpha I_E$

$I_B = I_C/\beta$

Regions of operation:



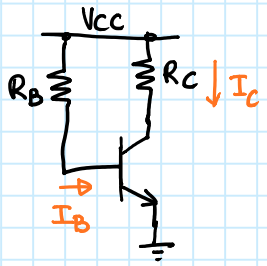
Cut off : $V_{EB} < 0$ & $V_{BC} > 0$

Forward active : $V_{EB} \sim 0.7$ & $V_{BC} > 0$

Saturation : $V_{EB} \sim 0.7$ & $V_{BC} < 0$

DC operating point calculation examples

(i)



Given: $V_{CC} = 2.5V$; $I_S = 5 \times 10^{-16} A$; $\beta = 100$

$R_B = 100k\Omega$; $R_C = 1k\Omega$

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

$$I_C = \beta I_B =$$

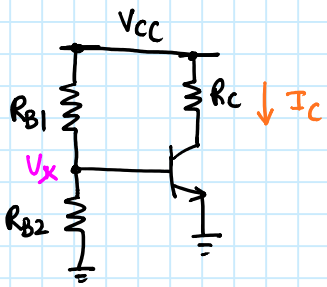
$$V'_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right)$$

$=$

$\Rightarrow$ More accurate $I_B = \frac{V_{CC} - V'_{BE}}{R_B} =$

$$I_C = \beta I_B =$$

(ii)



$V_{CC} = 2.5V$; $I_S =$

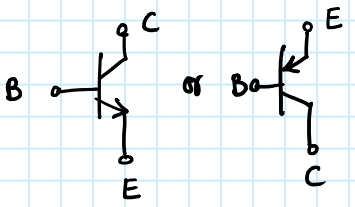
$R_{B1} = 17k\Omega$ $R_{B2} = 8k\Omega$ $R_C = 5k\Omega$ $\beta = 100$

$$V_X = V_{CC} \cdot \frac{R_{B2}}{R_{B2} + R_{B1}} = 800mV$$

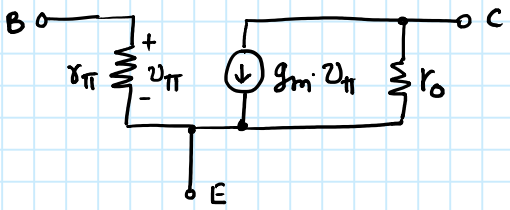
$$I_C = I_S \exp\left(\frac{V_X}{V_T}\right) = \quad \Rightarrow I_B =$$

More accurate $V_X = \frac{R_{B2}}{R_{B2} + R_{B1}} \left[V_{CC} - I_B \cdot R_{B1}\right]$

BJT incremental model :



$\Rightarrow$

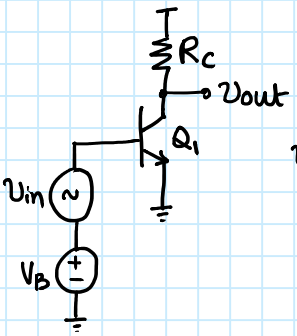


$$r_o = \frac{V_A}{I_C}$$

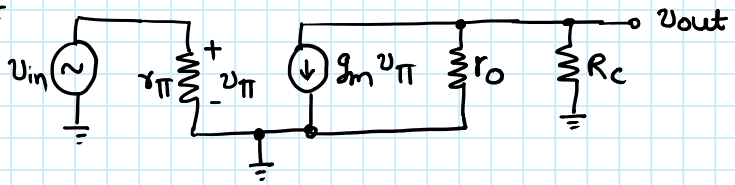
$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \beta \frac{\partial I_B}{\partial V_{BE}} = \frac{\beta}{r_\pi} \quad \text{or} \quad g_m r_\pi = \beta$$

BJT amplifiers :

Common emitter (CE) stage



V_B chosen to bias Q_1 in forward active region

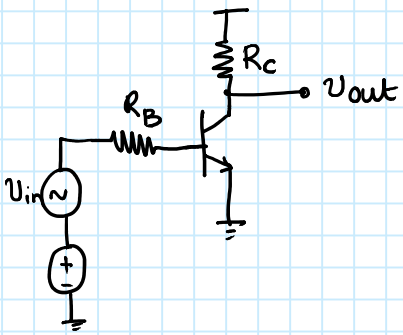


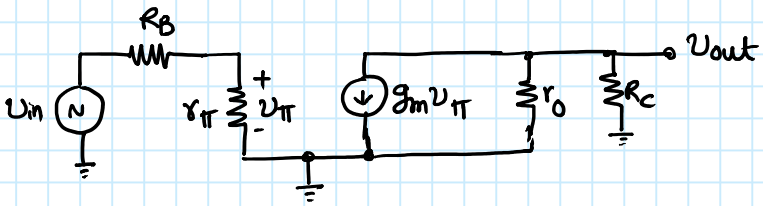
$$v_{out} = -g_m v_\pi \, (r_o \parallel R_C)$$

$$v_\pi = v_{in}$$

$$A_v = \frac{v_{out}}{v_{in}} = -g_m (r_o \parallel R_C) = -\frac{\beta}{r_\pi} \cdot (r_o \parallel R_C)$$

CE stage with base resistance





$$v_\pi = \frac{r_\pi}{R_B + r_\pi} \cdot v_{in}$$

$$\Rightarrow A_v = \frac{v_{out}}{v_{in}} = -\frac{g_m r_\pi}{R_B + r_\pi} \cdot (r_o \parallel R_C)$$

$$= -\frac{\beta}{R_B + r_\pi} (r_o \parallel R_C)$$