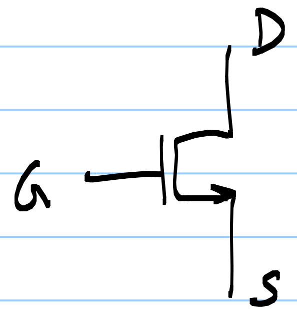
29/10/2020

Lecture 47

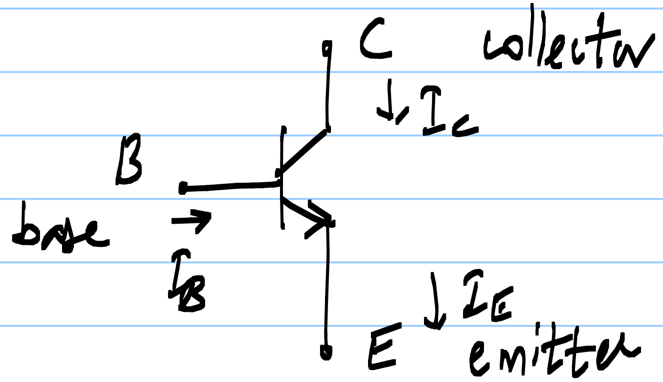
Bipolar Junction Transistor (BJT)



NMOS

cause - V_{GS}

effect - I_D

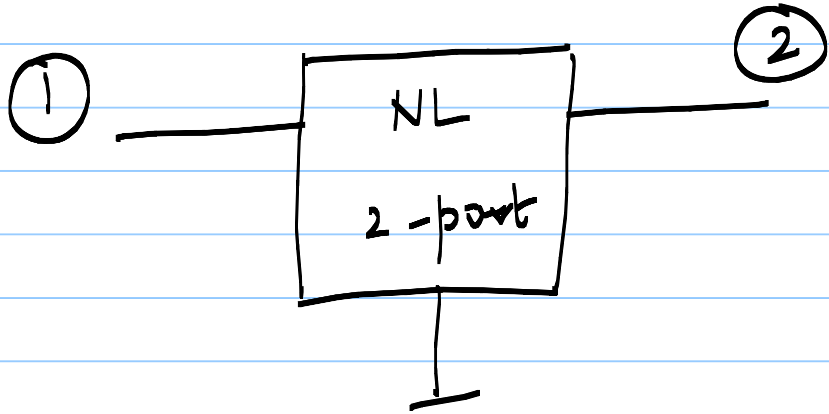


NPN transistor

cause - V_{BE}

effect - I_C

V_{BE} voltage controls I_C

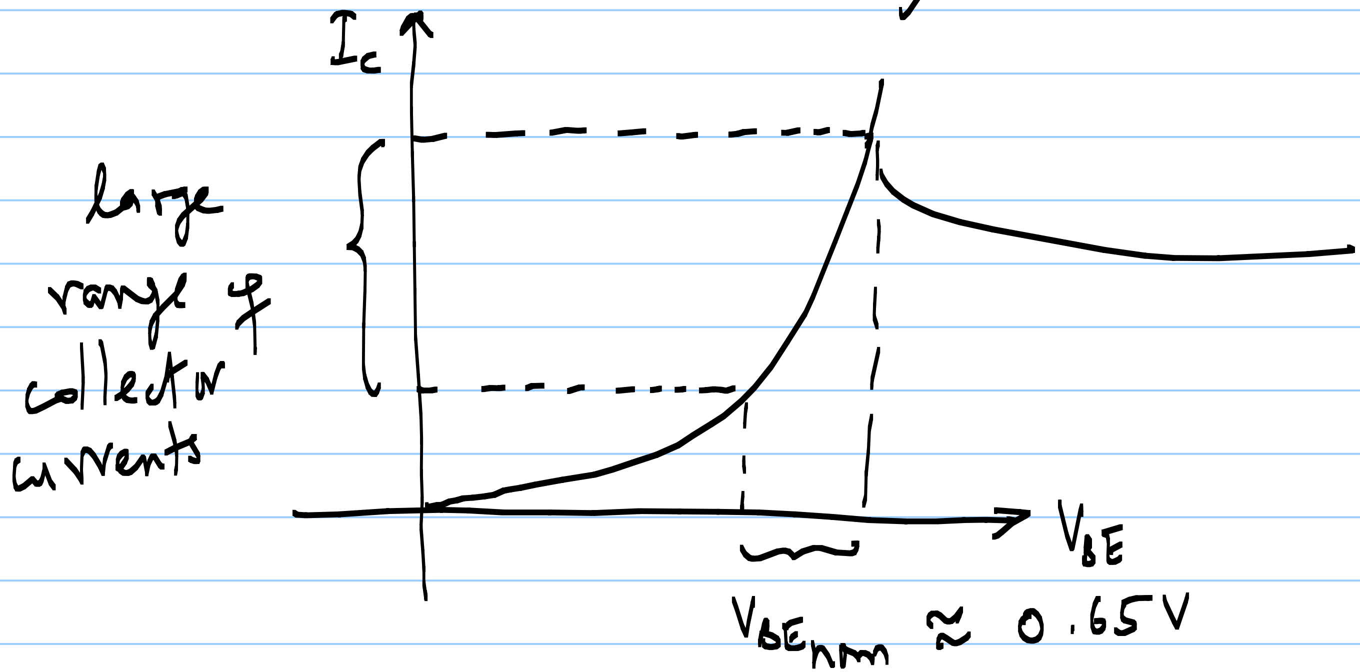


$$[y] = \begin{bmatrix} 0 & 0 \\ y_{21} & 0 \end{bmatrix}$$

y_{21} — as large as possible

I_1 = constant
$I_2 = g(V_1)$

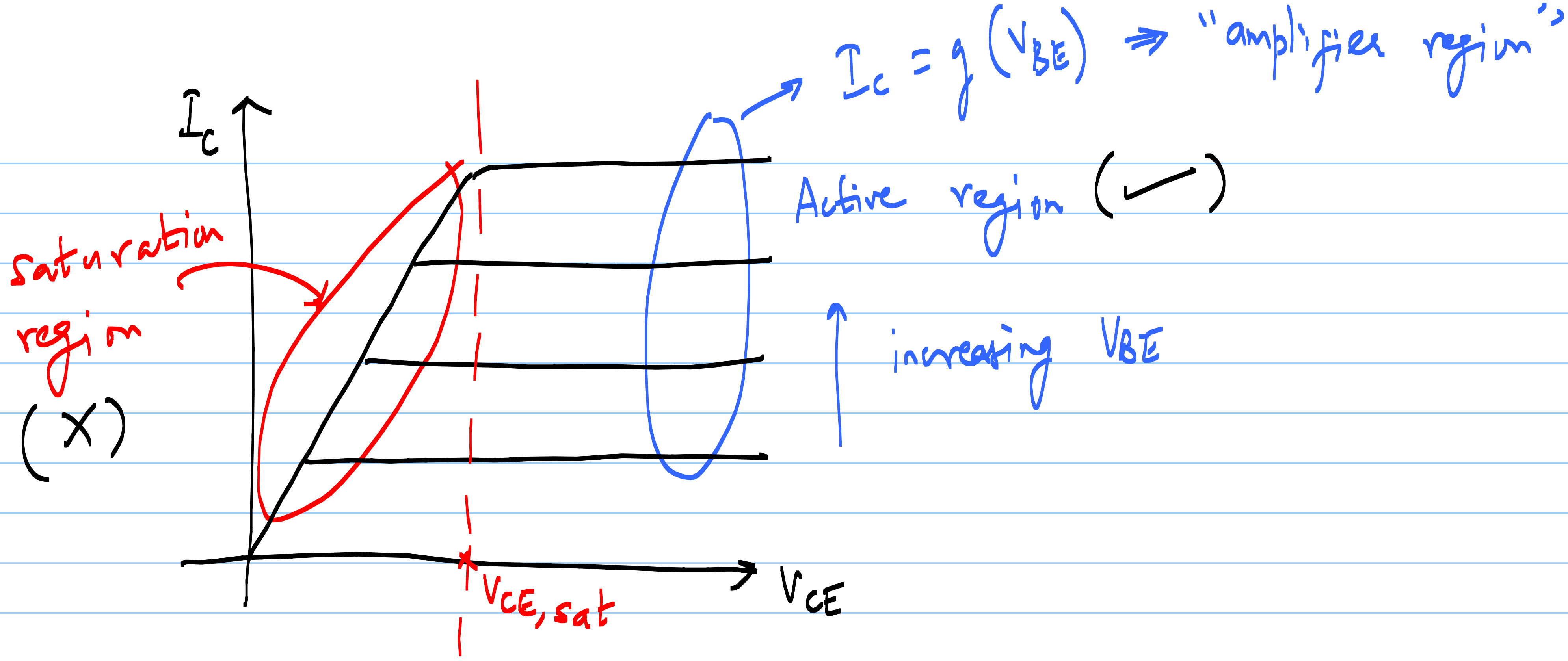
BJT also shares these characteristics



$$I_c = I_s\left[\exp\left[\frac{V_{BE}}{V_t}\right] - 1\right]$$

I_B = very small

$$V_t = \frac{kT}{q} \approx 25mV$$



When $V_{CE} > V_{CE,sat} \Rightarrow$ good amplifier

$V_{BE,on} \approx 0.65\,V, \quad V_t \approx 25\,mV$

* $I_c \approx I_s \exp\left(\frac{V_{BE}}{V_t}\right)$

* $V_{BE} = V_t \ln\left(\frac{I_c}{I_s}\right)$

* $I_B = \dfrac{I_C}{\beta}$

β = current gain of BJT

$\sim 50 - 200$, typically

* $I_E = I_C + I_B = (\beta+1) I_B = \left(\dfrac{\beta+1}{\beta}\right) I_C$

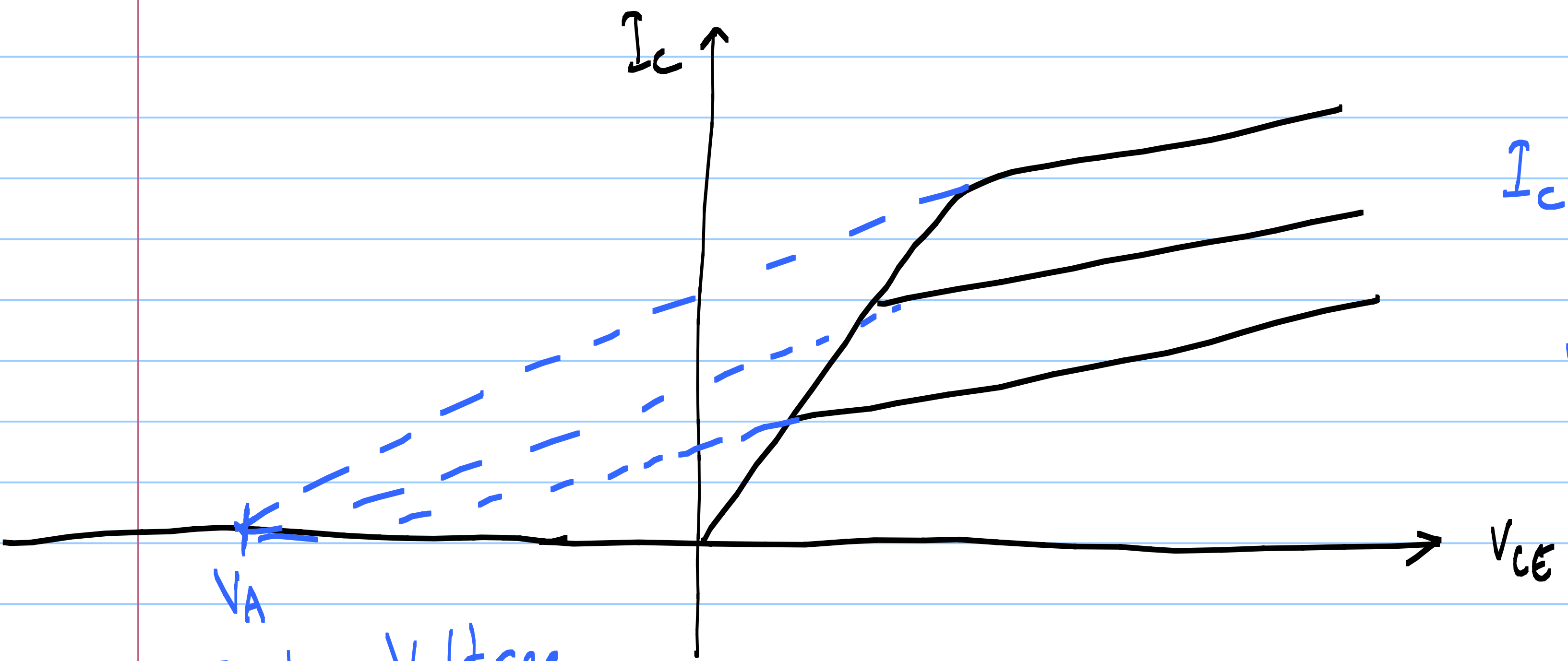
* Small signal parameters:

$$y_{11} = \frac{\partial I_B}{\partial V_{BE}} = \frac{1}{\beta}\frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{\beta V_t} = \frac{g_m}{\beta}$$

$$y_{12} = \frac{\partial I_B}{\partial V_{CE}} = 0$$

$$y_{21} = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_t} = g_m$$

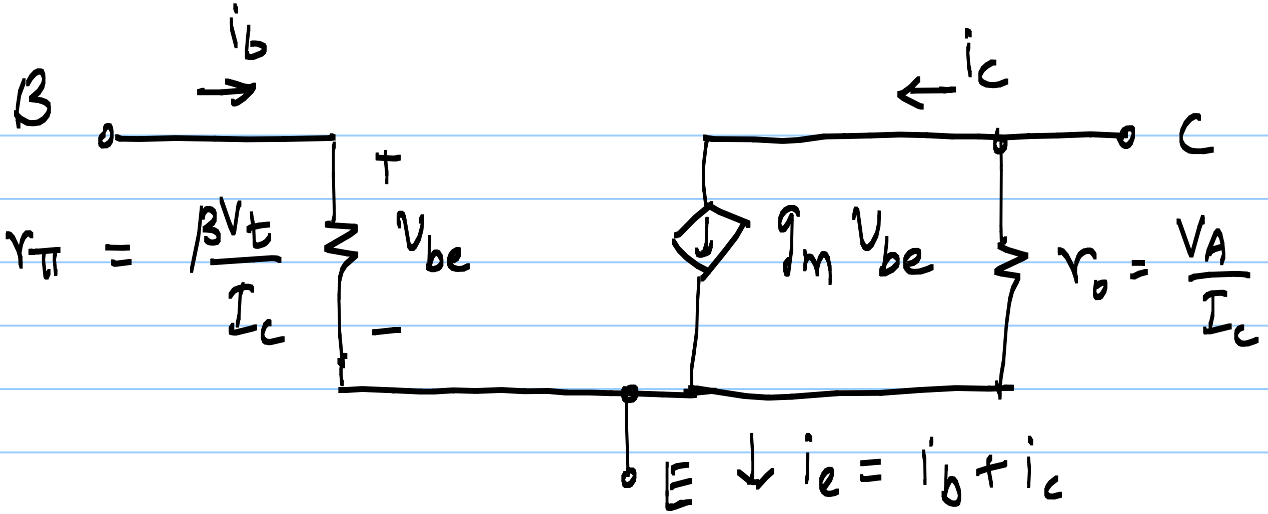
$$y_{22} = \frac{\partial I_C}{\partial V_{CE}} = 0$$ { very small in a real device }



$$I_c = \left[I_s \exp\left(\frac{V_{BE}}{V_t}\right)\right]\left[1 + \frac{V_{CE}}{V_A}\right]$$

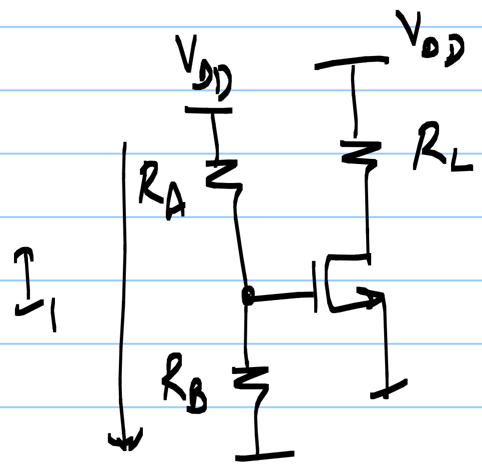
$V_A = -\infty$ for an ideal device with $y_{22} = 0$

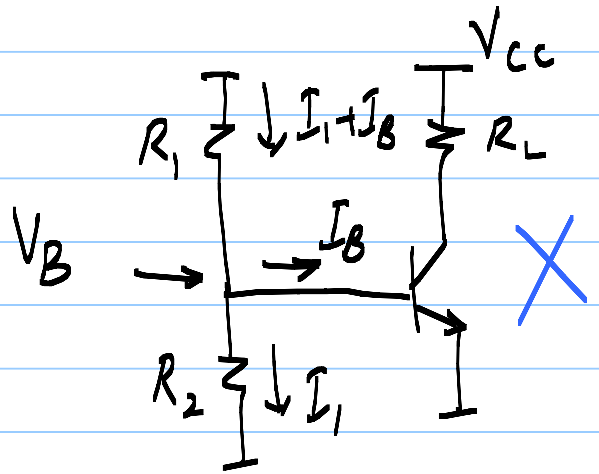
actual $y_{22} = \dfrac{I_c}{V_A}$



other small-signal representations exist

BJT Amplifiers





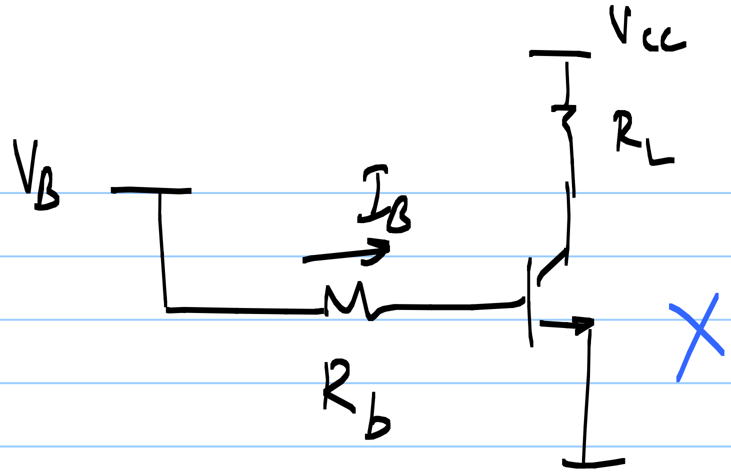
V_B will not be equal to desired bias value due to additional drop across R_1

choose R_A, R_B so that

$R_A \| R_B \gg R_s$

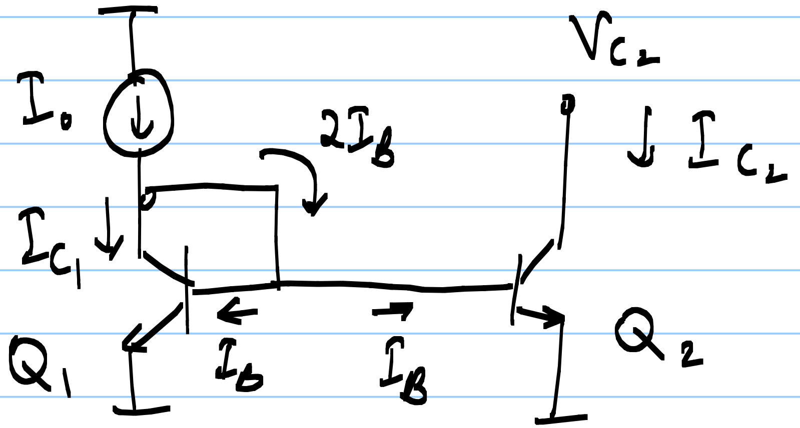
i.e. $V_B = f(I_B)$

$= f(I_c)$



BJT current mirror

o)



$Q_1 = Q_2$

$$I_{C_1} = I_0 - 2I_B$$

$$I_B = \frac{I_{C_1}}{\beta}$$

$$I_{C_1} = \frac{I_0 \cdot \beta}{\beta + 2}$$

$$V_{BE_1} = V_{BE_2} \Rightarrow I_{C_1} = I_{C_2} \Rightarrow I_{B_1} = I_{B_2} = I_B$$

when $V_{C_2} > V_{CE_{sat}}$