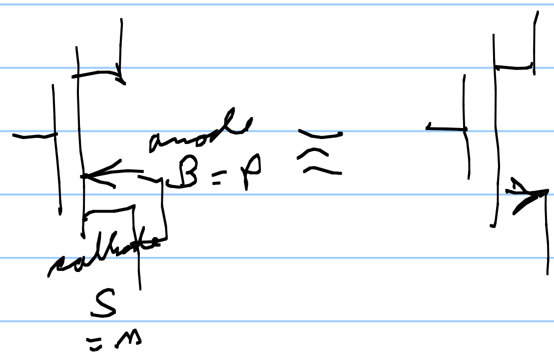
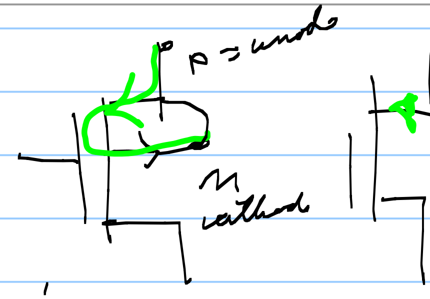
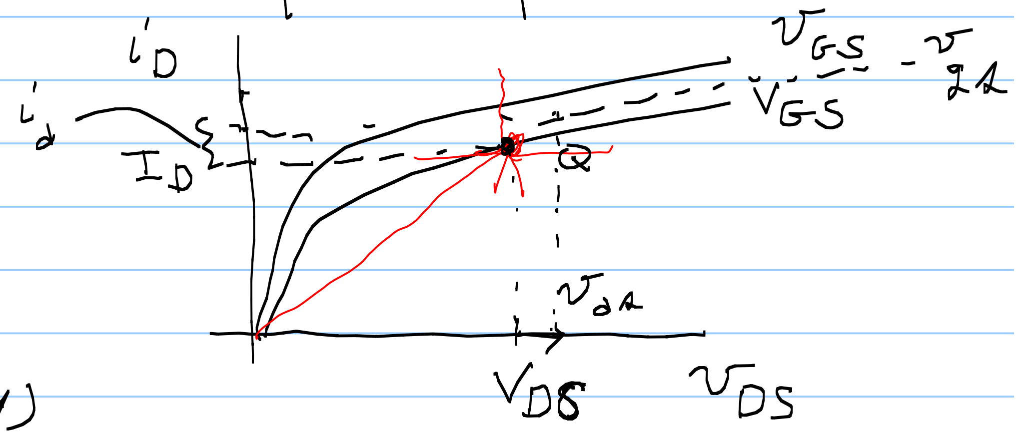
EE302

Note Title 3/11/2004







for signal analysis:

i_D = total

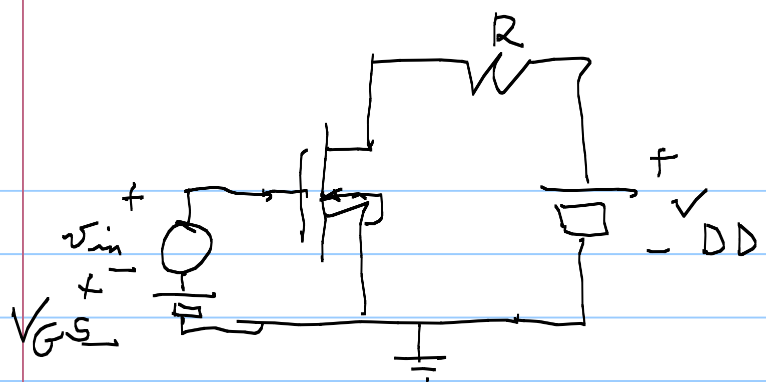
I_D = bias (DC state at Q point)

i_d = signal

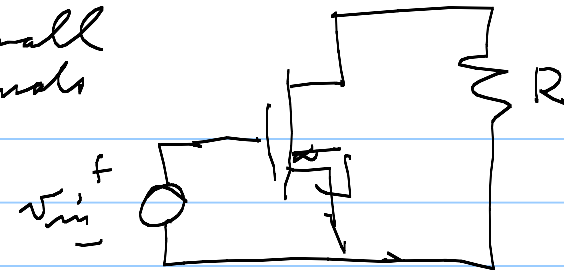
$$i_D = I_D + i_d$$

$$v_{DS} = V_{DS} + v_{ds}$$

i_d vs v_{ds} (v_{gs}) signal behavior



for small signals $\Longrightarrow$



small signal transistor

$$i_D(v_{GS}, v_{DS}) = \underbrace{I_D}_{\substack{\| \\ i_D(V_{GS},\, V_{DS})}} + \frac{\partial i_D}{\partial v_{GS}}\Big|_Q \underbrace{(v_{GS} - V_{GS})}_{\substack{\| \\ v_{gs}}} + \frac{\partial i}{\partial v_{DS}}\Big|_Q \underbrace{(v_{DS} - V_{DS})}_{v_{ds}}$$

$$\underbrace{+\ \partial^2 \ \ldots\ldots}$$

V_{GS}, V_{DS}: Q pt values

if $|v_{GS} - V_{GS}|$, $|v_{DS} - V_{DS}|$ are small we can ignore

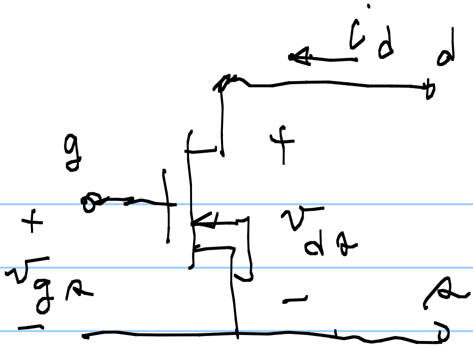
$$i_D = I_D + \underbrace{i_d}_{\text{signal}}$$

$$i_d = \frac{\partial i_D}{\partial v_{GS}}\Big|_Q v_{gs} + \frac{\partial i_D}{\partial v_{DS}}\Big|_Q v_{ds}$$

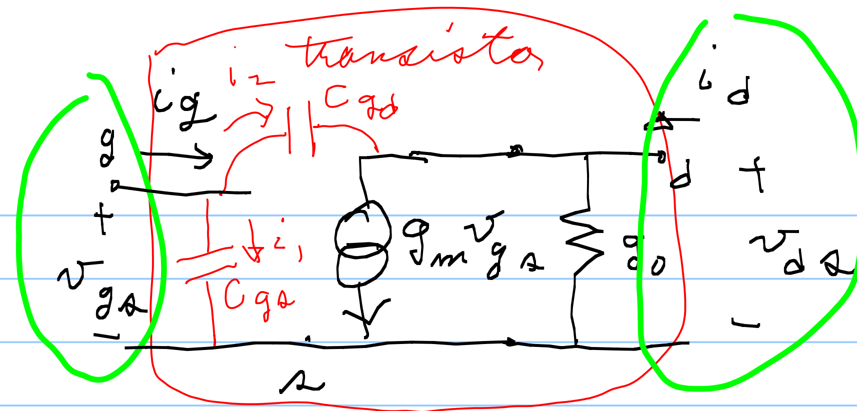
$$= g_m v_{gs} + g_o v_{ds}$$

g_m = mutual conductance

g_o = output conductance



$\Rightarrow$



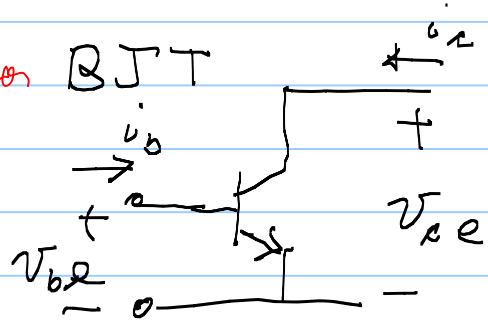
= 2-port equivalent circuit has an admittance

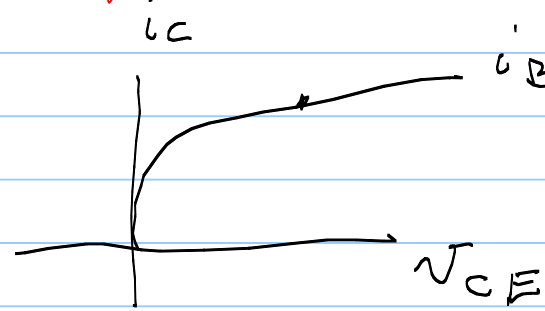
$$\begin{bmatrix} i_g \\ i_d \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ g_m & g_o \end{bmatrix} \begin{bmatrix} v_{gs} \\ v_{ds} \end{bmatrix} \Rightarrow \begin{bmatrix} sC_{gs} + sC_{gd} & -sC_{gd} \\ -sC_{gd} + g_m & sC_{gd} + g_o \end{bmatrix} = Y(s)$$

$s = d/dt$ or Laplace transform variable

$$i_g = \underbrace{sC_{gs} \cdot v_{gs}}_{i_1} + \underbrace{sC_{gd}(v_{gs} - v_{ds})}_{i_2}$$

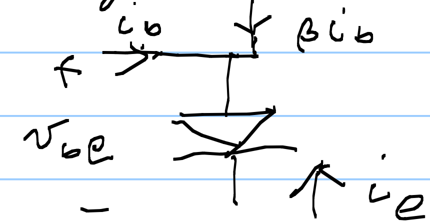
for BJT





$$i_C = I + i_c \; ; \quad i_c = \underbrace{\left.\frac{\partial i_C}{\partial v_{CE}}\right|_Q v_{ce}}_{g_o \cdot v_{ce}} + \underbrace{\left.\frac{\partial i_C}{\partial i_B}\right|_Q \cdot i_b}_{\beta \cdot i_b}$$

note at the base we have a forward biased diode usually for small signals



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

$$-i_E = -I_E + \frac{\partial(-i_E)}{\partial v_{BE}}(v_{BE} - V_{BE}) \; ; \quad \frac{\partial(-i_E)}{\partial v_{BE}} = I_S \cdot \frac{1}{V_T} \cdot \left. e^{\overset{V_{BE}}{\overset{\shortparallel}{v_{BE}}}/V_T}\right|_Q \approx \frac{-I_E}{V_T}$$

at Q point $-i_E = -I_E \approx I_S e^{V_{BE}/V_T} >> I_S$

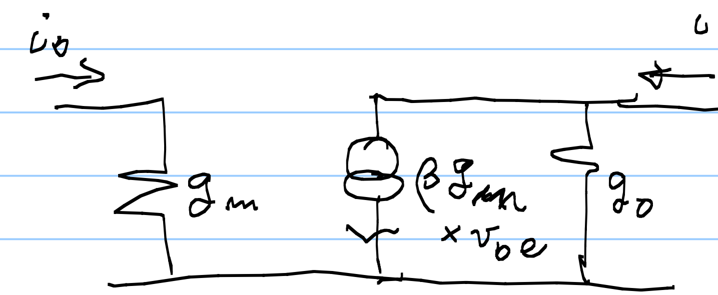
$$I_C + I_B + I_E = 0 \Rightarrow I_E = -I_C - I_B \Rightarrow I_E = -I_C - \frac{I_C}{\beta} = \frac{(\beta+1)}{\beta}(-I_C)$$

$$-i_e = i_b + \beta i_b \Rightarrow -i_e = (\beta+1)\, i_b \Rightarrow -i_e = (\beta+1)\, i_b = \left(\frac{-I_E}{V_T}\right) v_{be}$$

$$i_b = \frac{-I_E}{(\beta+1)V_T} \cdot v_{be} = \frac{I_C}{\beta V_T} \cdot v_{be} = g_{in} \cdot v_{be}$$

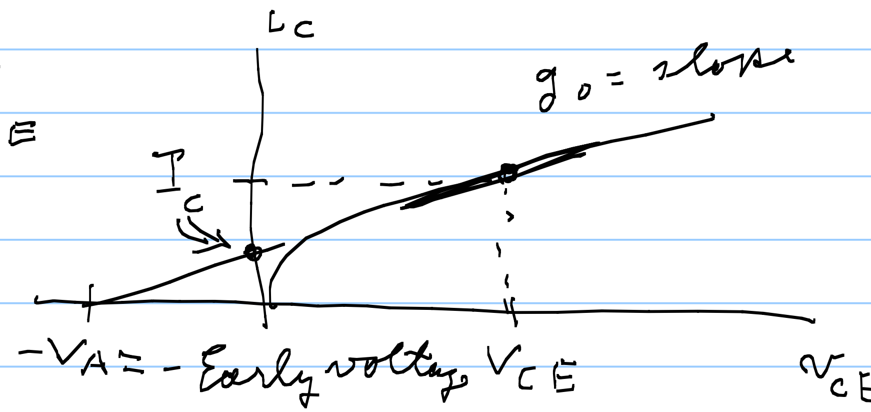
$\equiv$

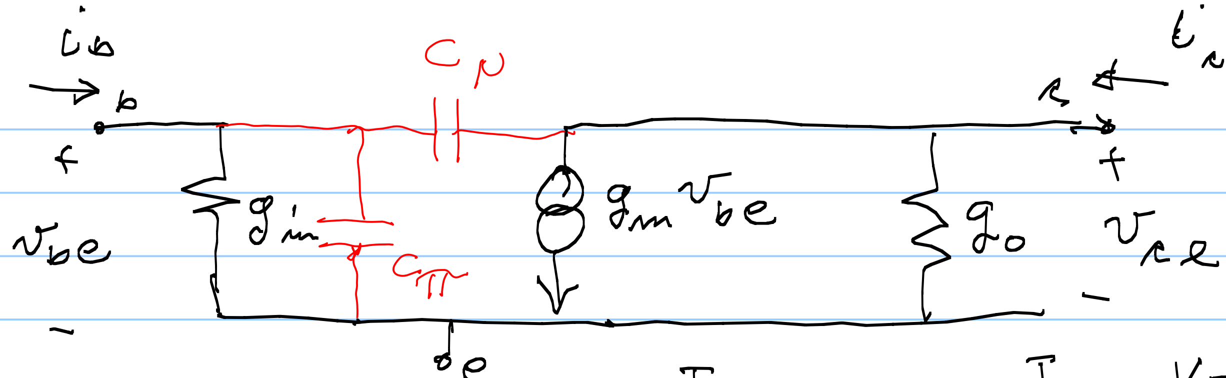
$$i_b = g_{in} v_{be}$$



$$g_{in} = \frac{I_C}{\beta V_T} = \frac{1}{\beta} g_m$$

$$\beta g_{in} = \frac{I_C}{V_T} = g_m \; ; \quad g_o = \frac{\partial i_c}{\partial v_{CE}} \approx \frac{I_C}{V_A}$$





$$g_\pi = g_{in} = \frac{g_m}{\beta} \qquad g_m = \frac{I_C}{V_T} \qquad g_o = \frac{I_C}{V_A} = \frac{V_T}{V_A} \cdot g_m$$

Π equivalent
a Y matrix
one
intrinsic
transistor

The hybrid-π