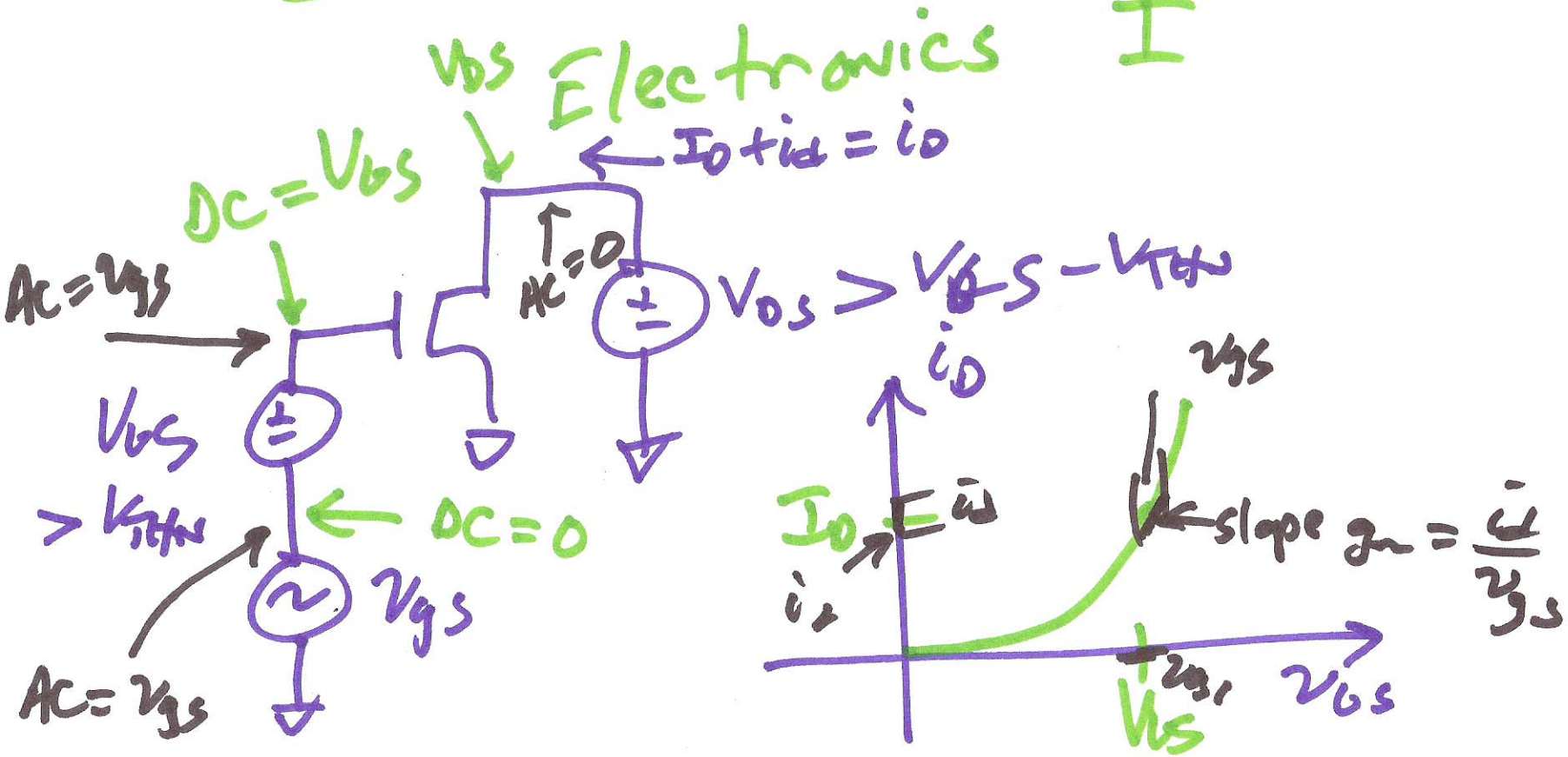
EE 320
April 29, 2015
Lecture 26
Electronics I



$$g_m = \left.\frac{\delta \overbrace{\frac{I_D + i_d}{i_D}}}{\delta V_{GS}}\right|_{\substack{V_{DS}=\text{const} \\ I=\text{const}}} = \frac{\delta}{\delta V_{GS}} \frac{\beta}{2}(V_{GS}-V_{TH})^2$$

$$\frac{\delta \frac{Kx^2}{2}}{\delta x} = Kx \cdot \frac{\delta x}{\delta x}$$

$$= \beta(V_{GS}-V_{TH})$$

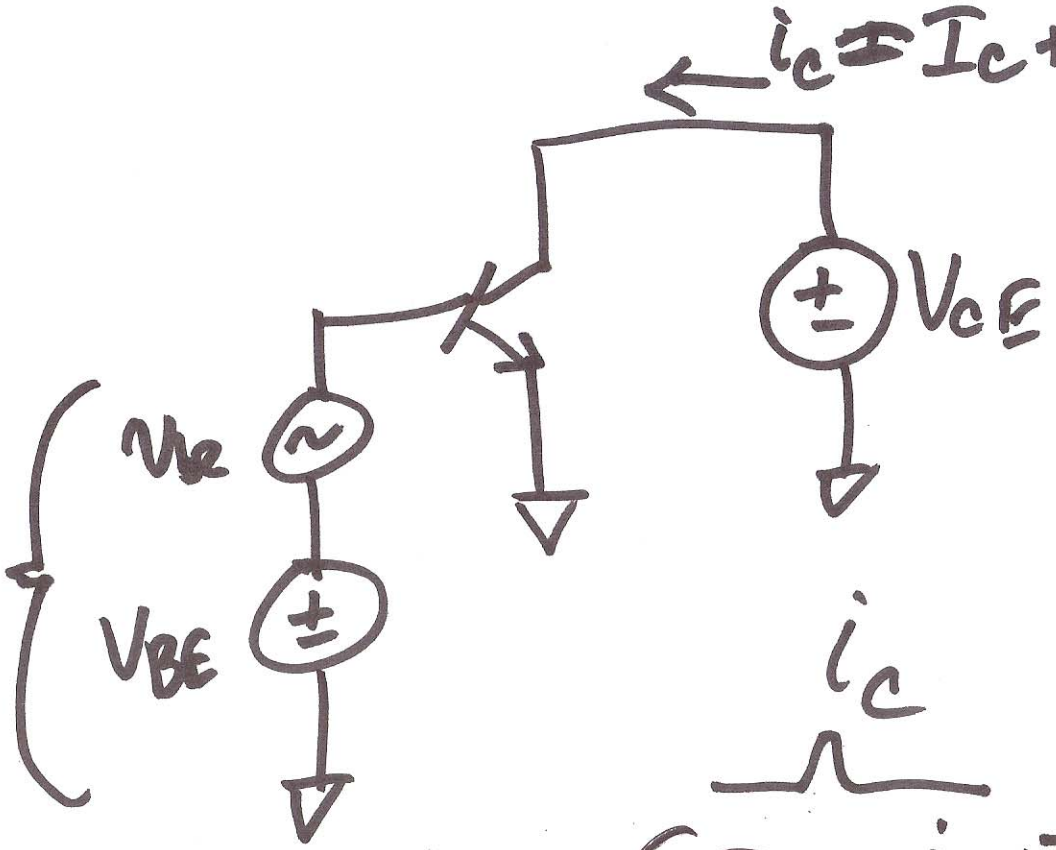
$$g_m = \beta(V_{DS}+2v_{gs}-V_{TH})$$

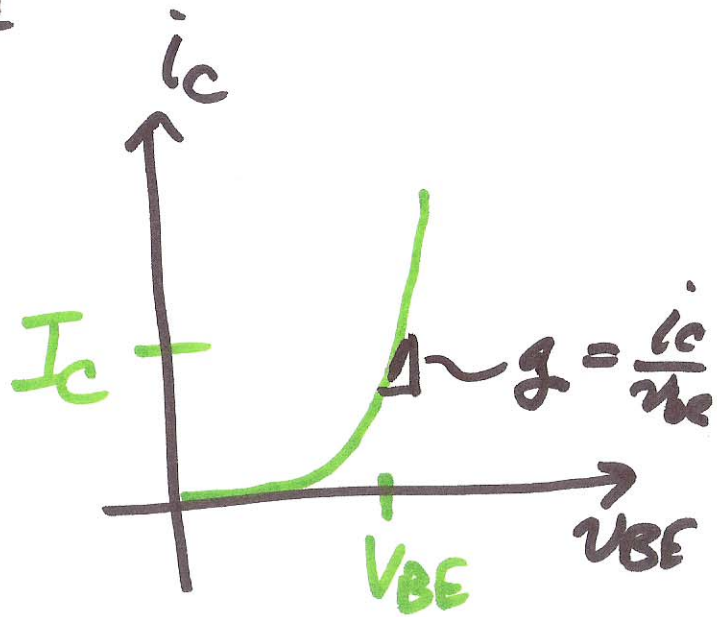
small-signal approx

$$V_{GS} \gg 2v_{gs}$$

$$\beta = KP \cdot \frac{W}{L} = \mu_n \cdot C_{ox} \cdot \frac{W}{L}$$

$$g_m \approx \beta(V_{GS}-V_{TH})$$





$$g_m = \frac{\delta I_C + i_c}{\delta V_{BE}} \Big/ I_C = \text{const}, \; V_{BE} = \text{const}$$

$$= I_S e^{\frac{v_{be}+V_{BE}}{nV_T}}$$

$$= \frac{1}{nV_T} I_S e^{\frac{v_{be}+V_{BE}}{nV_T}}$$

$$= \frac{i_C}{nV_T}$$

$$\frac{d}{dx} e^{kx} = k e^{kx}$$

S.S. approx. $I_C \gg i_c$

$$g_m = \frac{I_C}{nV_T}$$

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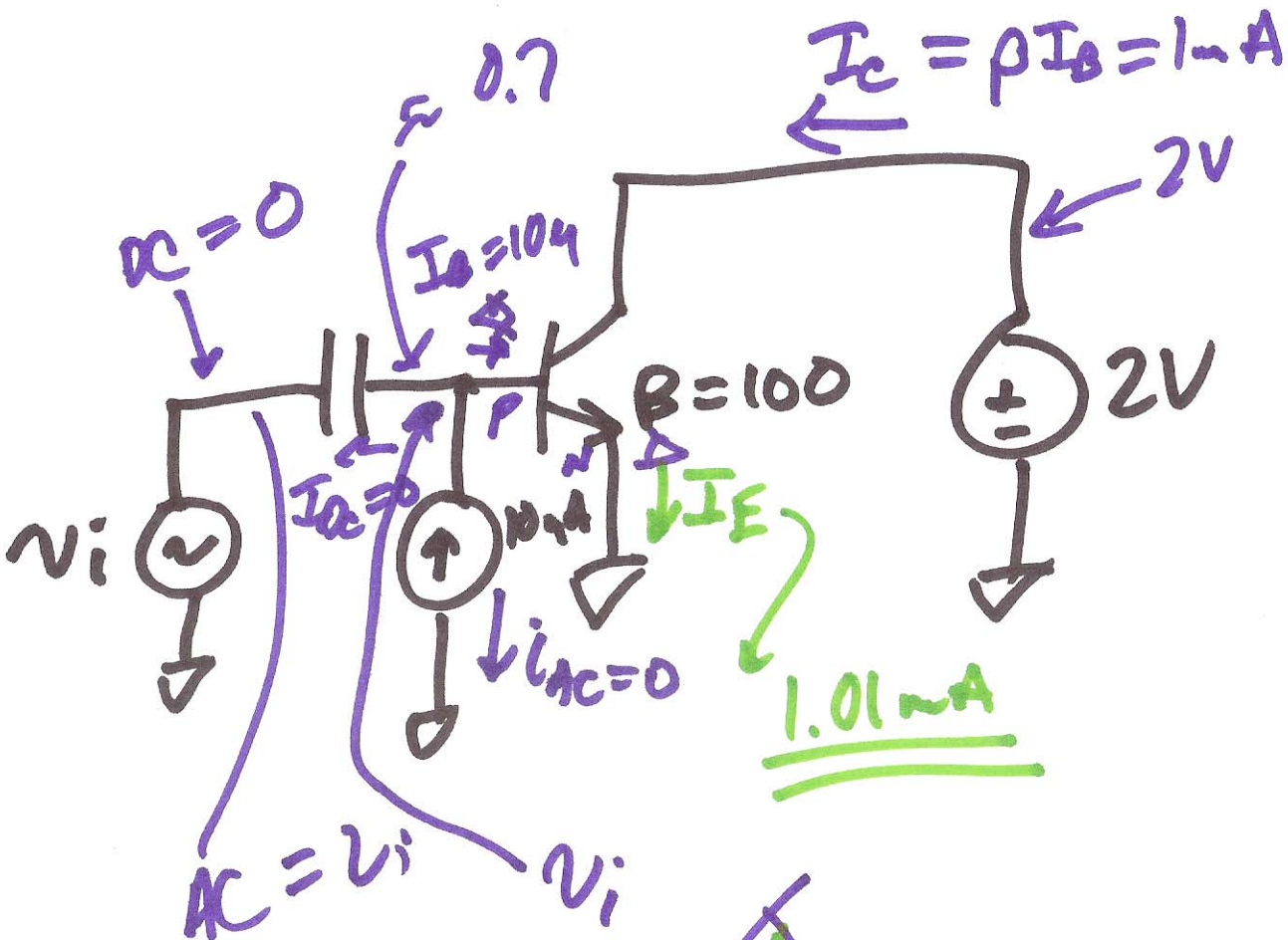


find i_C

$$g_m = \frac{I_C}{nV_T} = 40\frac{mA}{V}$$

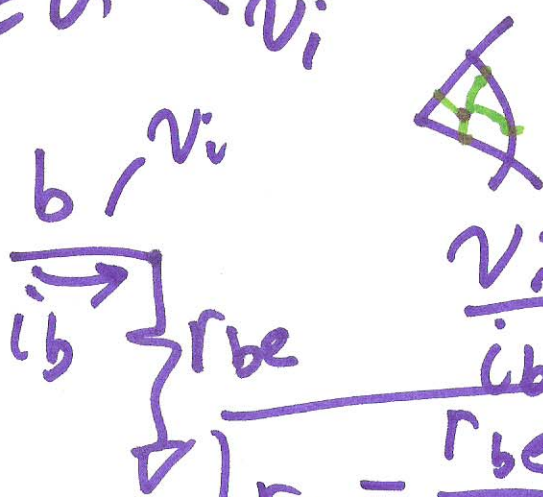
$$i_C = g_m v_i$$

$$\boxed{i_C = 0.04 v_i}$$

$$i_b = \frac{i_C}{100} = \frac{i_C}{\beta}$$

$$i_e = i_b + i_C$$

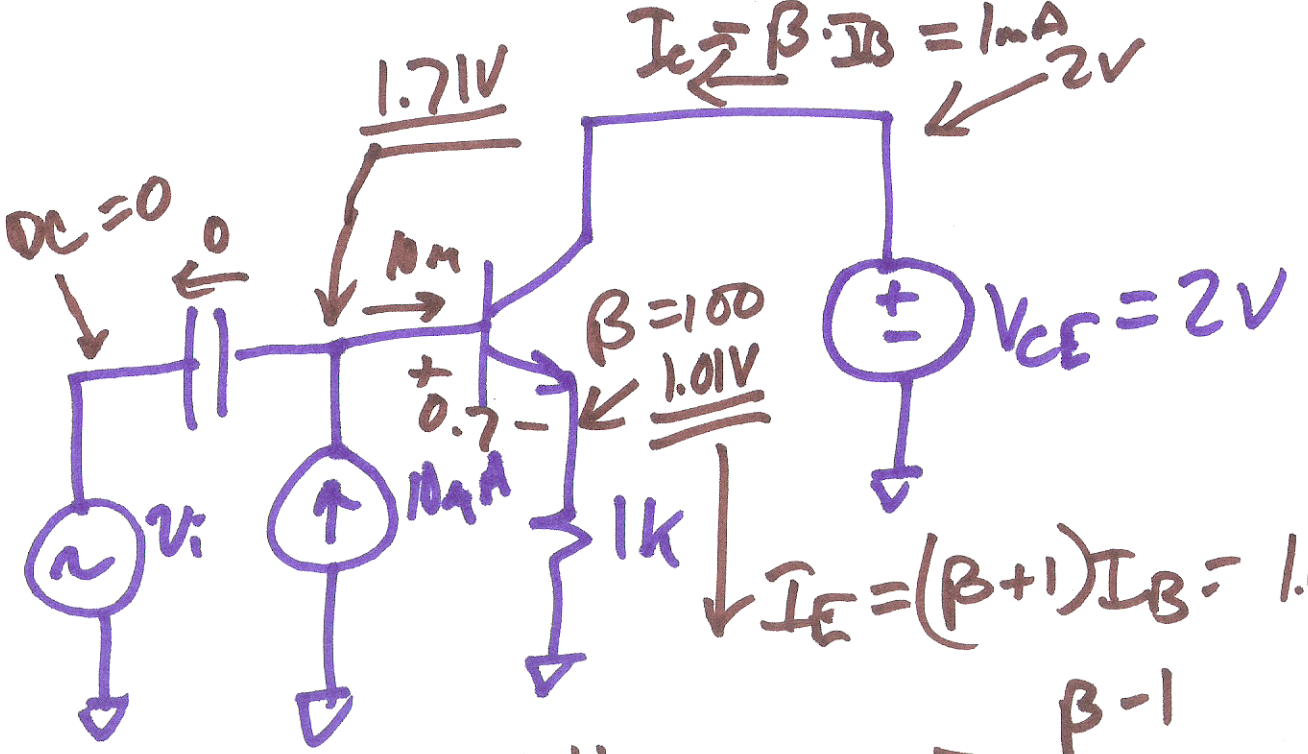
$$= i_b \cdot (\beta + 1)$$



$$\frac{v_i}{i_b} = \frac{i_C/g_m}{\frac{i_C}{\beta}}$$

$$\boxed{r_e = \frac{r_{be}}{\beta+1} = \frac{nV_T}{I_E}}$$

$$= \frac{\beta}{g_m} = \frac{\beta \cdot V_T n}{I_C} = \frac{V_T \cdot n}{I_B} = r_{be}$$



$$i_C = g_m v_{be}$$

$$\beta \cdot i_b = i_c$$

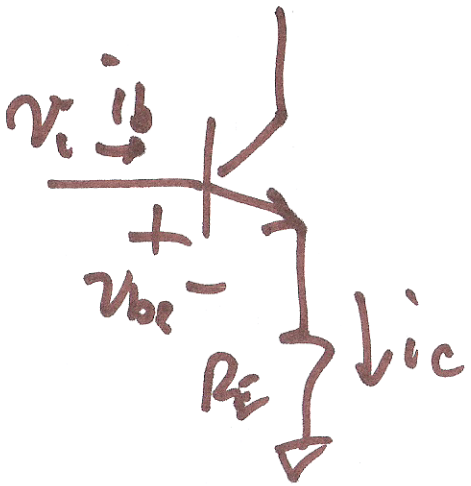
$$(\beta+1) i_b = i_e$$

$$R_{\text{with base}} = \frac{v_i}{i_b} \Big\|$$

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

$$i_e = i_c \cdot \alpha$$

$$v_i = r_{be} \cdot i_b + i_b R_E (\beta+1)$$



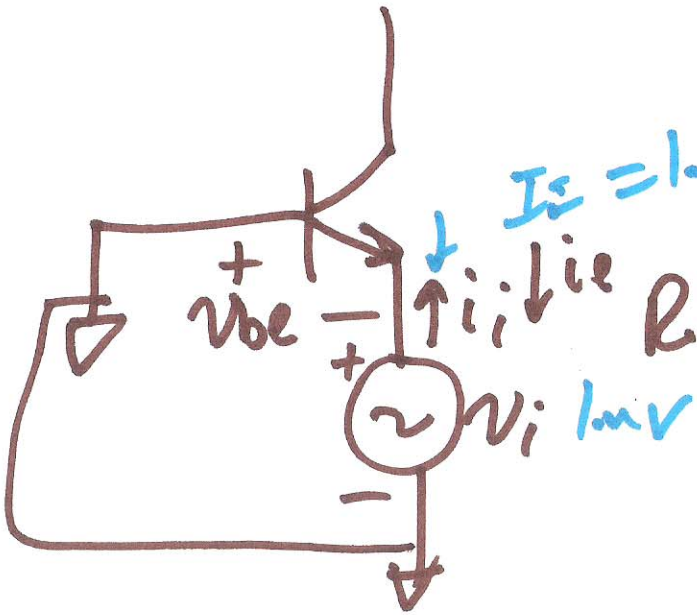
$$v_i = v_{be} + R_E \cdot i_e$$

$$= \frac{i_C}{g_m} + R_E \cdot i_C \alpha$$

$$v_i = i_C \left(\frac{1}{g_m} + \alpha R_E \right)$$

$$i_e = \frac{1mV}{r_e} = \frac{1mV}{25}$$

$$r_e = \frac{NV_T}{1mA} = 25\Omega$$



$$R_{in\,to\,source} = \frac{v_i}{i_i} = \frac{v_{be}}{i_e} \Rightarrow$$

$$v_i + v_{be} = 0$$

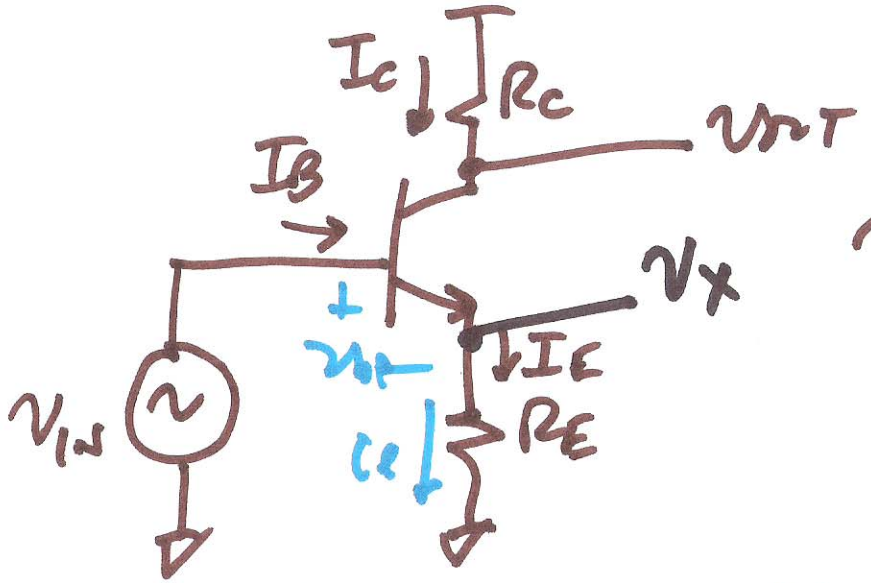
$$v_i = -v_{be}$$

$$i_i = -i_e$$

$$R_{in\,to\,source} = \frac{v_{be}}{i_b \cdot (\beta+1)} = \frac{r_{be}}{\beta+1}$$

$$= r_e$$

$$r_e = \frac{NV_T}{I_E} = \frac{NV_T}{I_B(\beta+1)}$$



$$\frac{v_{OUT}}{v_{IN}} = ?$$

$$i_c = v_{be} \cdot g_m$$

$$v_{IN} = v_{be} + i_e \cdot R_E$$

$$\frac{v_X}{v_{IN}} = \frac{i_e \cdot R_E}{v_{be} + i_e \cdot R_E}$$

$$v_{IN} = \frac{i_c}{g_m} + \frac{i_c}{\alpha} \cdot R_E$$

$$v_{be} = i_b \cdot r_\pi$$

$$= i_e \cdot r_e$$

$$= i_e \cdot \frac{g_m}{\alpha}$$

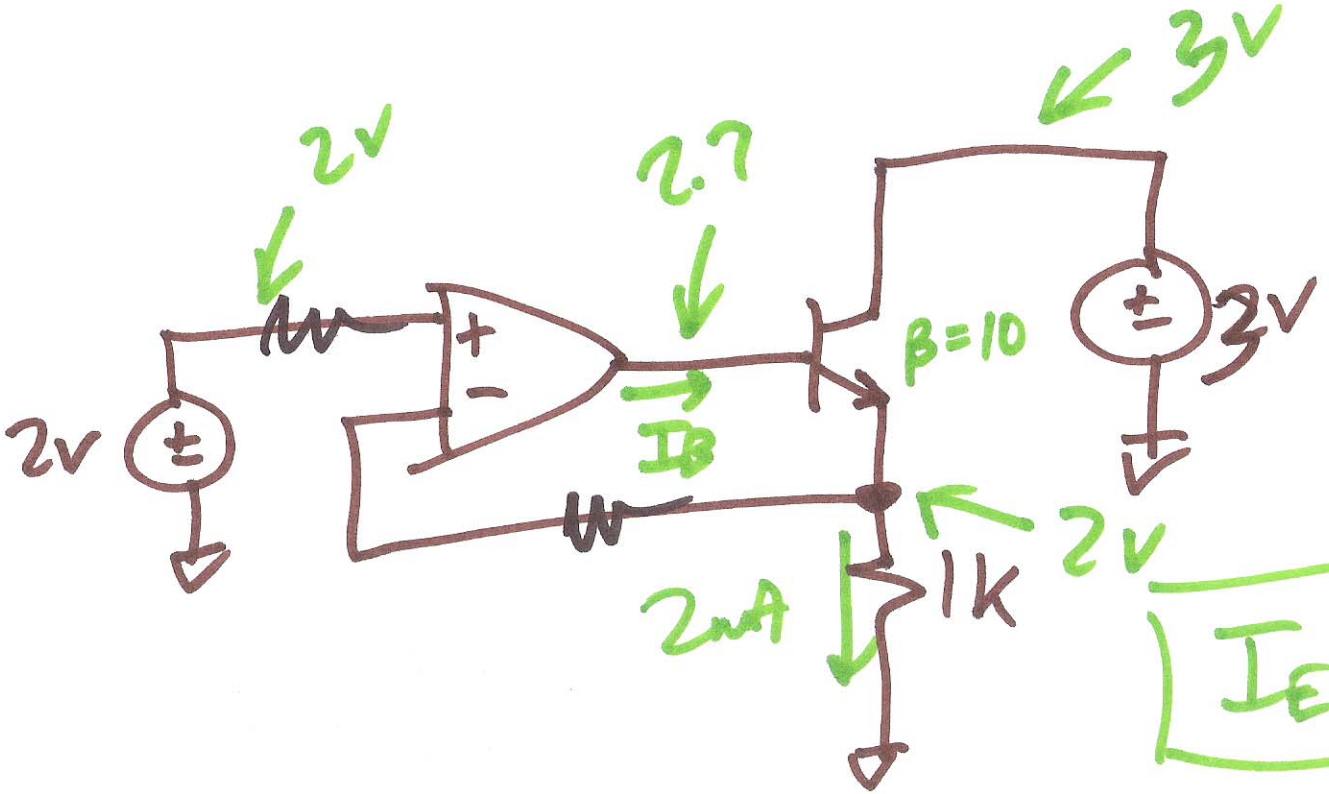
$$r_e \quad \frac{I_C}{V_T \cdot \alpha}$$

$$\frac{v_X}{v_{IN}} = \frac{R_E}{r_e + R_E}$$

$$v_{OUT} = -i_C \cdot R_C$$

$$\frac{v_{OUT}}{v_{IN}} = \frac{-R_C}{\frac{1}{g_m} + \frac{R_E}{\alpha}}$$

$$\frac{I_C}{\alpha} = I_E$$



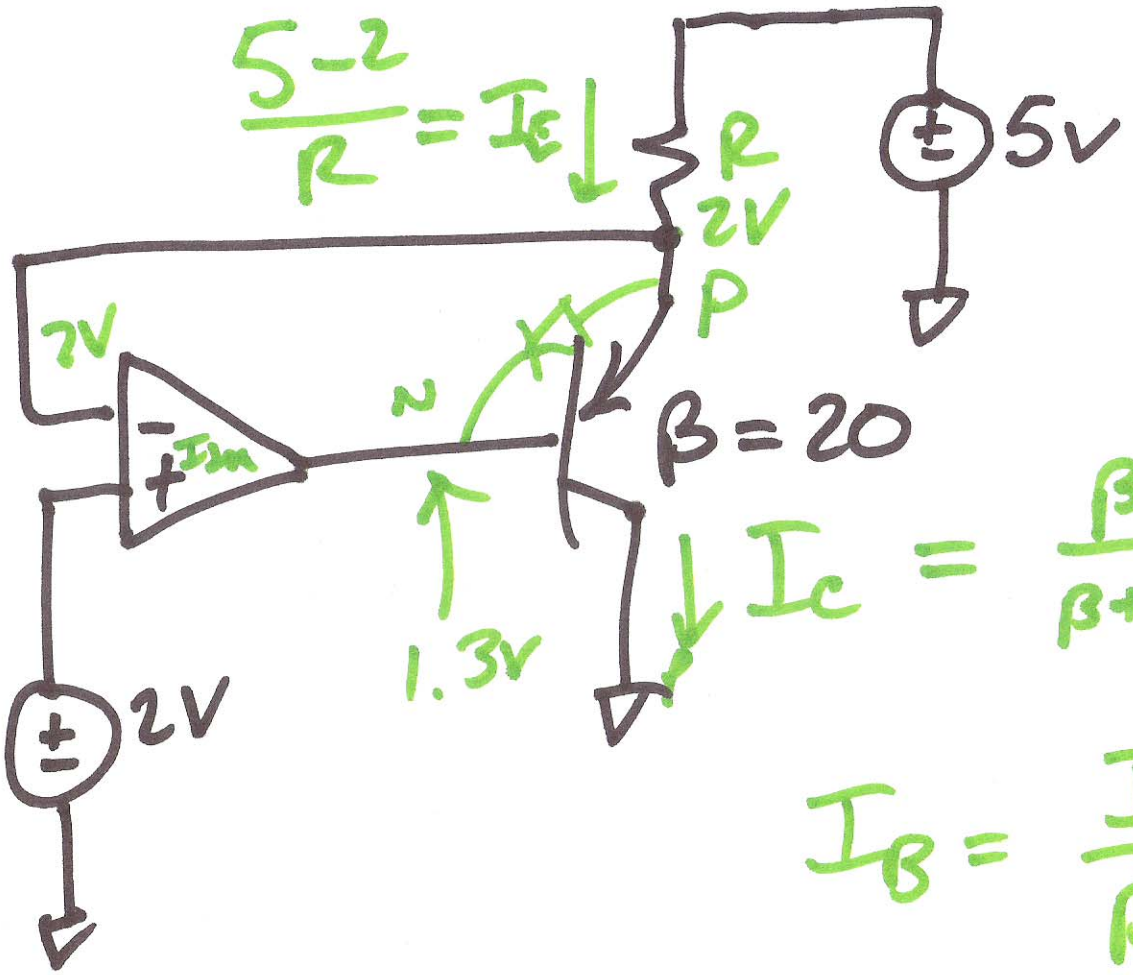
$I_B \cdot \beta = I_C$

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

$I_E = 2mA$

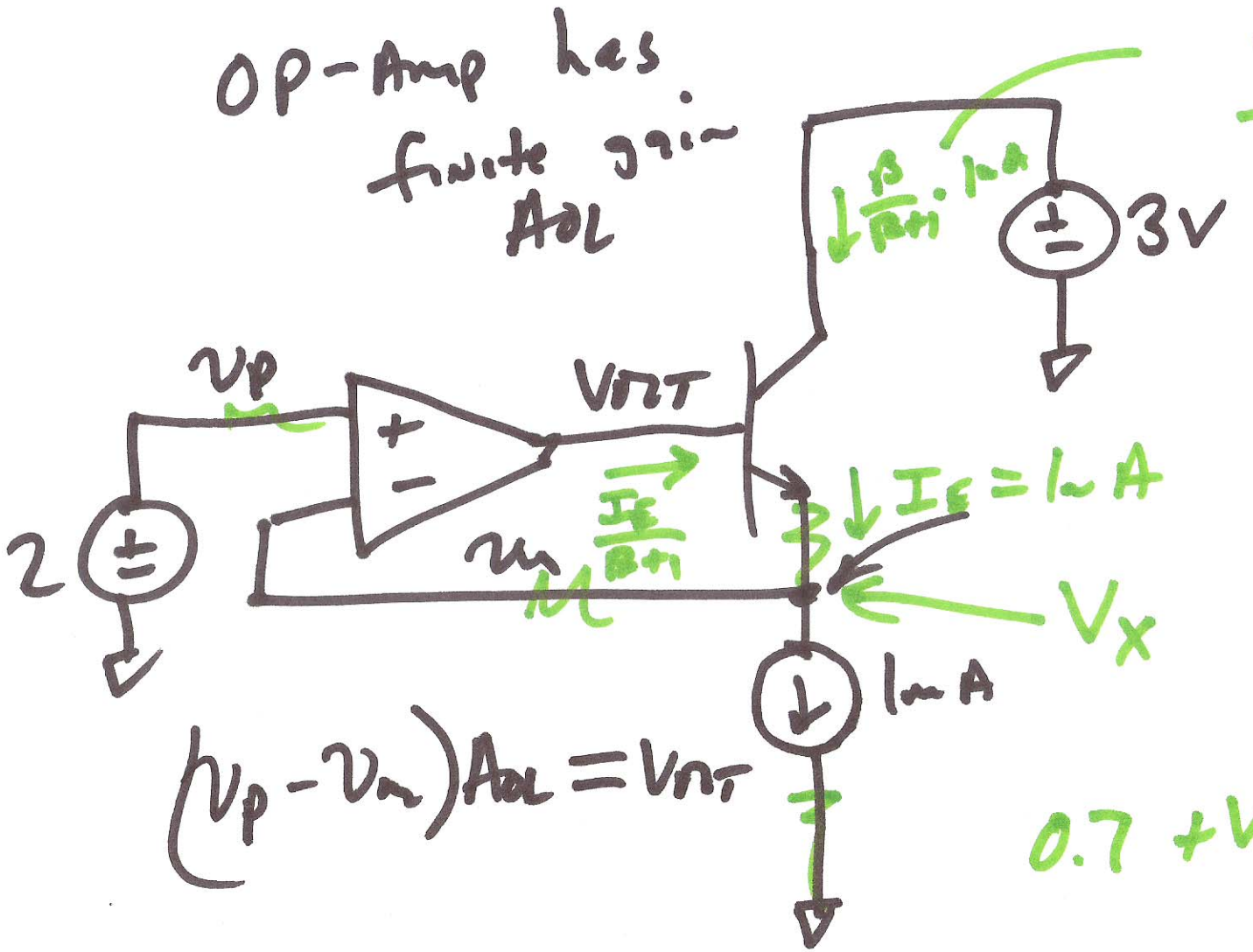
$I_B = \frac{2mA}{11}$

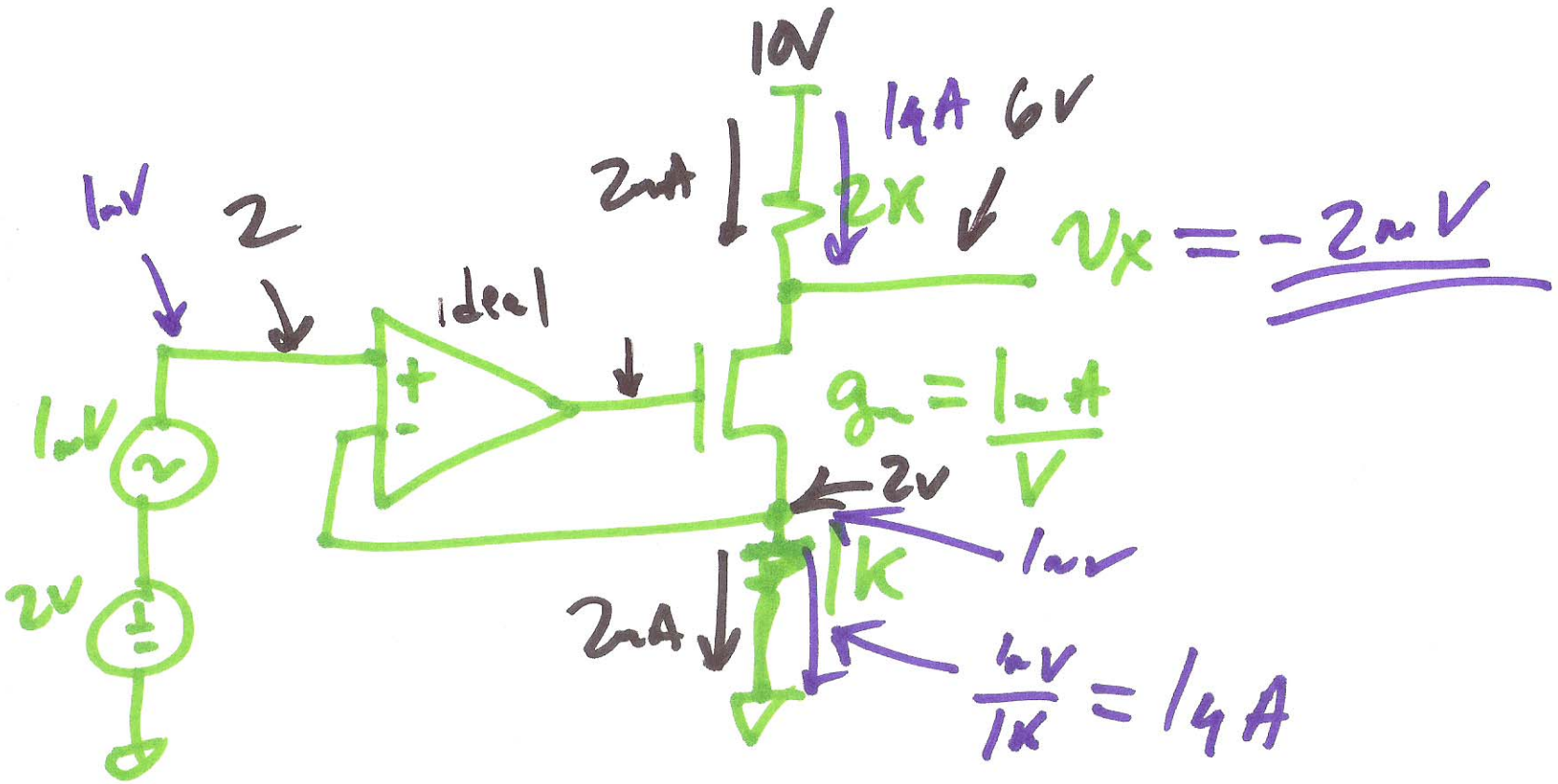
$I_C = \frac{10}{11} \cdot 2mA$



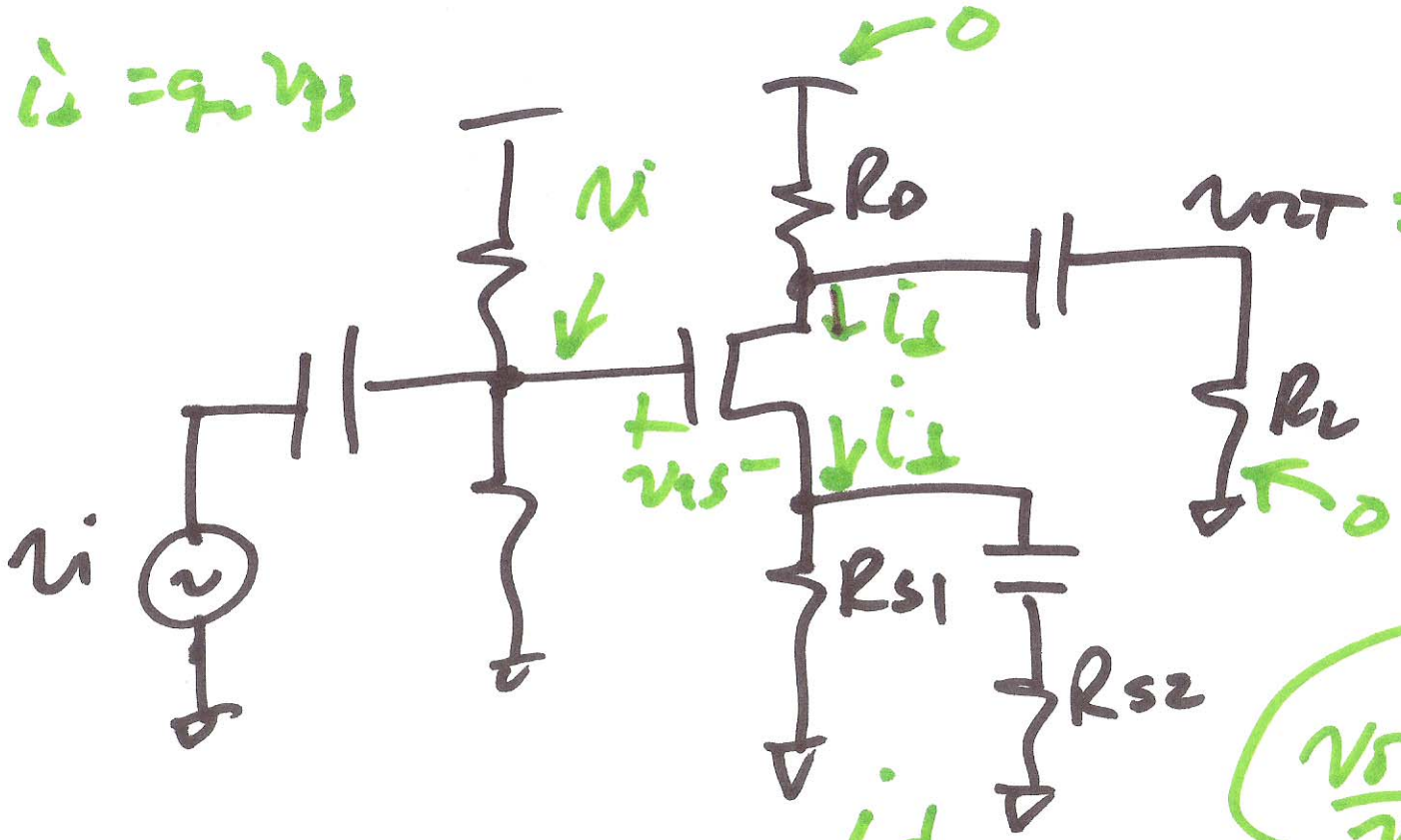
$$I_C = \frac{\beta}{\beta+1} \cdot I_E = \alpha I_E$$

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


OP-Amp has finite gain A_{OL}
$\frac{\beta}{\beta+1} \cdot 1mA =$
$\propto I_E$
3V
v_p
V_{OUT}
v_n
$\frac{I_E}{\beta+1}$
$I_E = 1mA$
V_X
2
1mA
$(v_p - v_n)A_{OL} = V_{OUT}$
$V_{OUT} = 0.7 + V_X$
$0.7 + V_X = A_{OL}(2 - V_X)$


10V
1mA 6V
2mA
2K
$v_x = -2mV$
1mV
2
ideal
1mV
2V
$g_m = \frac{1mA}{V}$
2V
1mV
1K
2mA
$\frac{1mV}{1K} = 1mA$

$i_d = g_m v_{gs}$



$v_{out} = -i_d \cdot R_D \| R_L$

$$\frac{v_{out}}{v_i} = \frac{-R_D \| R_L}{\frac{1}{g_m} + R_{S1} \| R_{S2}}$$

$$v_i = v_{gs} + i_d (R_{S1} \| R_{S2})$$

$$v_i = i_d \left(\frac{1}{g_m} + R_{S1} \| R_{S2} \right)$$