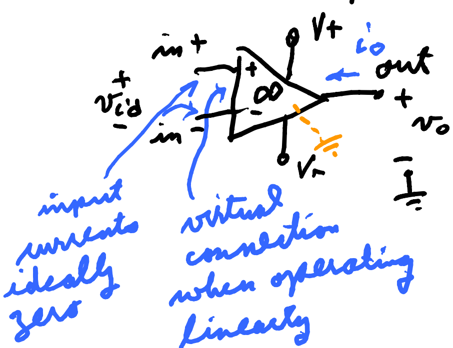
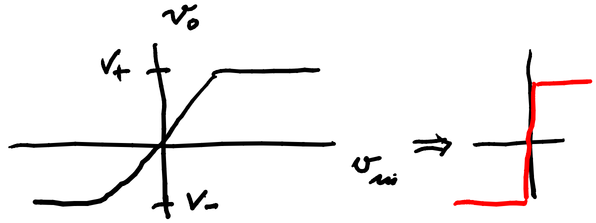
EE 303
02/16/10

next time
biasing BJT = p.437, fig 5.44
MOS = p.282, fig 4.30

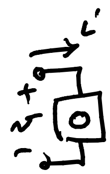
Come with a bare paper next period

op-amps 741 (⇒ 1548, 2 in a package)
p.894





nullator = input (passive)

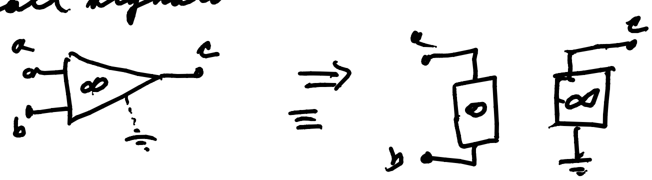


$v = 0$
$i = 0$

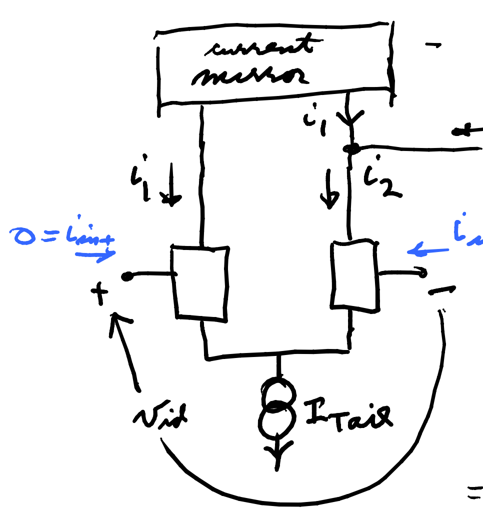
norator (active)

v = arbitrary
i = arbitrary independent of v

for small signals

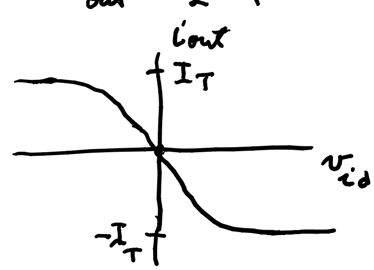


We make these with differential pairs and current sources & mirrors



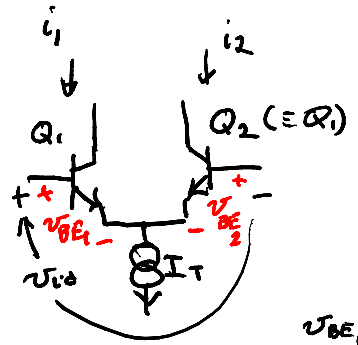
$I_{tail} = i_1 + i_2 = I_T$

$i_{out} = i_2 - i_1$



called OTA
= operational transconductance amplifier

for BJT, p. 710, MOS, p. 721; OTA(MOS) = p. 728



law for forward active region

$$i_c = \alpha I_s e^{v_{BE}/V_T}$$

$$v_{id} = v_{BE_1} - v_{BE_2}$$

$$I_T = i_1 + i_2 = \alpha I_S \left(e^{v_{BE_1}/V_T} + e^{v_{BE_2}/V_T}\right)$$

$$= \alpha I_S e^{v_{BE_2}/V_T}\left[e^{(v_{BE_1} - v_{BE_2})/V_T} + 1\right]$$

$$i_o = i_2 - i_1 = \alpha I_S \left(e^{v_{BE_2}/V_T} - e^{v_{BE_1}/V_T}\right)$$

$$= \alpha I_S e^{v_{BE_2}/V_T}\left[1 - e^{(v_{BE_1} - v_{BE_2})/V_T}\right]$$

$$\frac{i_o}{I_T} = \frac{\left[1 - e^{v_{id}/V_T}\right]}{\left[1 + e^{v_{id}/V_T}\right]} = \frac{e^{v_{id}/2V_T}}{e^{v_{id}/2V_T}}\left[\frac{e^{-v_{id}/2V_T} - e^{v_{id}/2V_T}}{e^{-v_{id}/2V_T} + e^{v_{id}/2V_T}}\right]$$

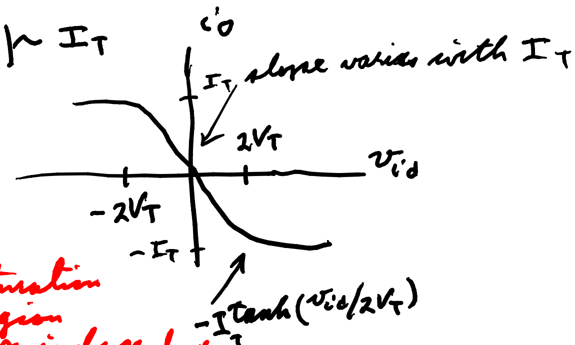
$$= -\frac{\sinh(v_{id}/2V_T)}{\cosh(v_{id}/2V_T)}$$

$$i_o = -I_T \tanh\left(\frac{v_{id}}{2V_T}\right)$$

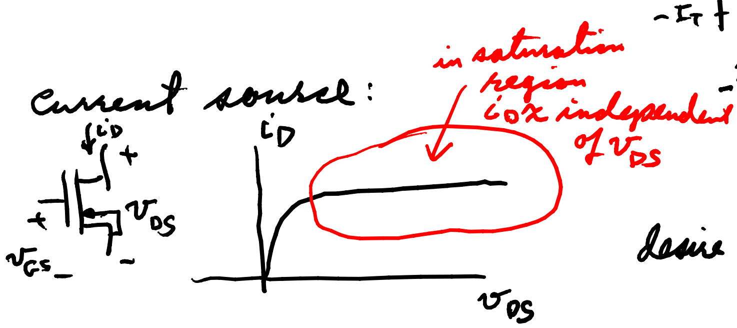
$V_T = 0.026\ v$

$2V_T = 0.052\ v$

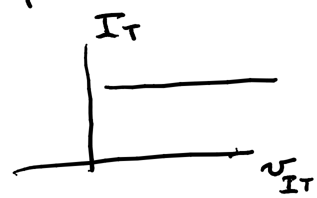
at v_{id} near 52 mv $|i_o| \sim I_T$

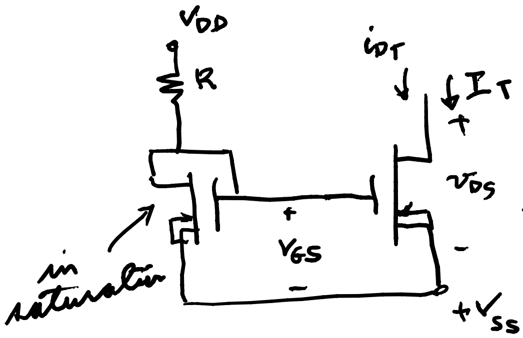


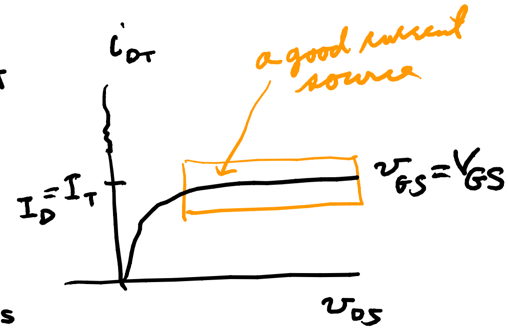
current source:



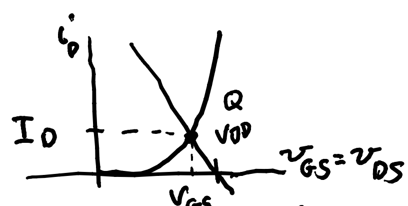
desire







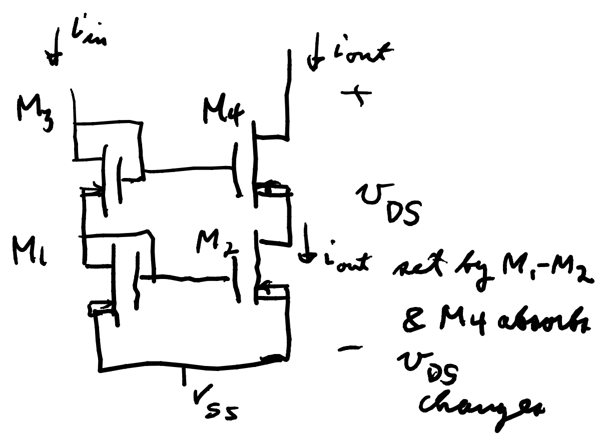
$v_{DS} - VTO = v_{GS} - VTO < v_{DS}$

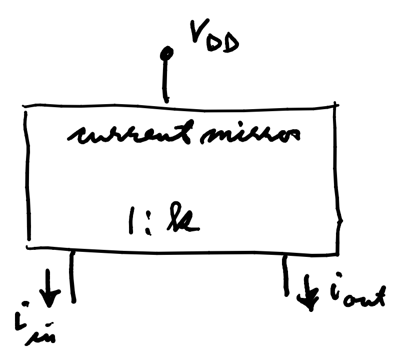


$$i_D = \frac{KP}{2}\frac{W}{L}(v_{GS} - VTO)^2$$

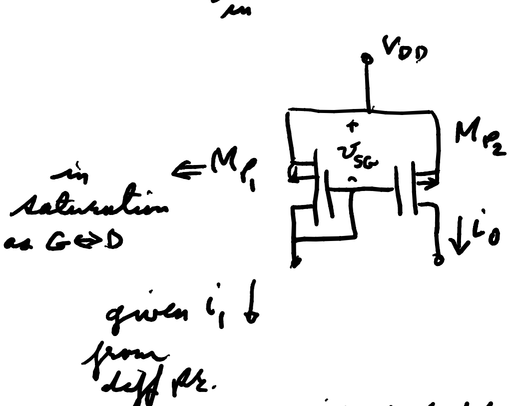
To make with less slope (larger V_A = Early voltage $= 1/\lambda$ for MOS)

use a cascode, p. 892





$i_{out} = k\, i_{in}$

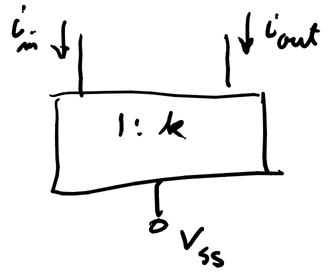


$$i_1 = \frac{KP}{2}\frac{W_1}{L_1}\left(v_{SG} - |VTO|_p\right)^2$$

$$i_0 = \frac{KP}{2}\frac{W_0}{L_0}\left(v_{SG} - |VTO|_p\right)^2 \text{ if } M_{P_2} \text{ in saturation}$$

$$\frac{i_0}{i_1} = \frac{W_0/L_0}{W_1/L_1} \Rightarrow k = \frac{W_0/L_0}{W_1/L_1}$$

gives a current mirror source



current mirror
sink