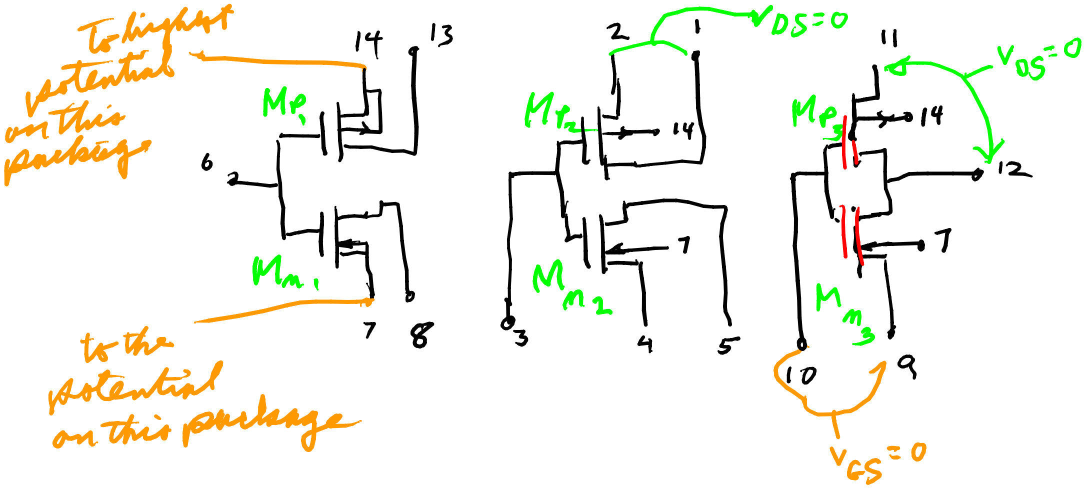
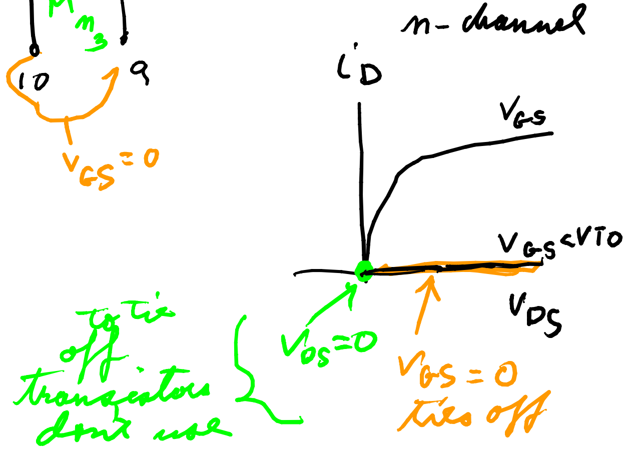
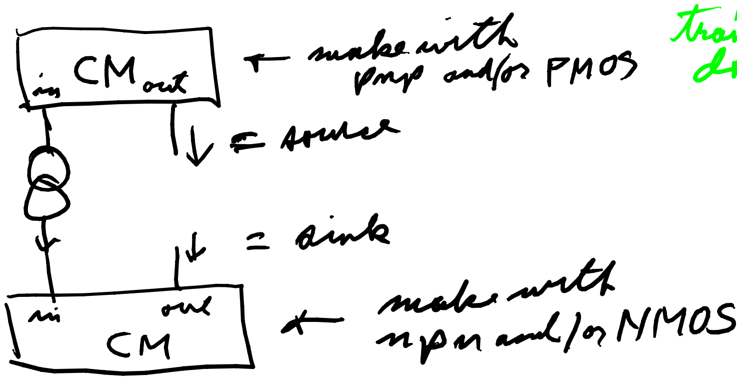
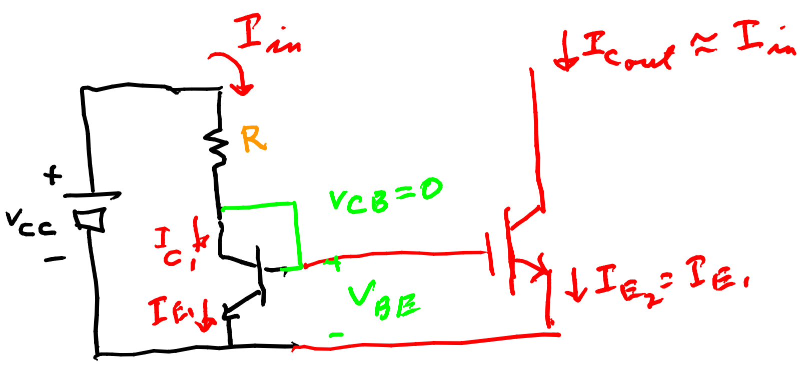
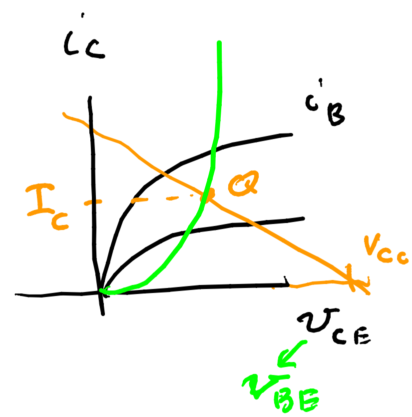
EE 303 H
02/19/09



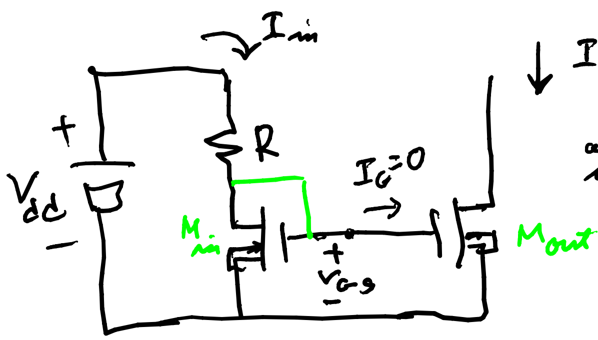








Current mirrors CMOS

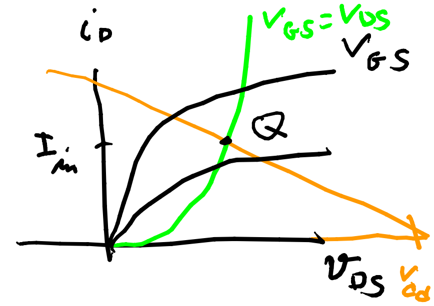


$\downarrow I_{out} = I_{in}$ if $M_{out} = M_{in}$ and M_{out} is in saturation

$V_{DS} = V_{GS}$

$> V_{GS} - VTO$

M_{in} is in saturation



M_{in}: $i_D = \frac{KP}{2}\frac{W}{L}(v_{GS} - VTO)^2 \Rightarrow I_D = Q$ point design value

$V_{GS} = VTO + \sqrt{\frac{I_{in}}{\frac{KP}{2} W/L}}$; $V_{dd} = R I_{in} + V_{GS}$

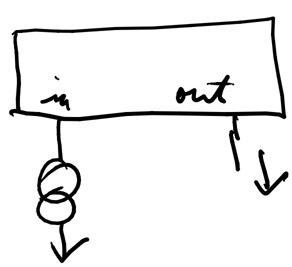
$\Rightarrow R = \frac{V_{dd} - V_{GS}}{I_{in} - 0}$

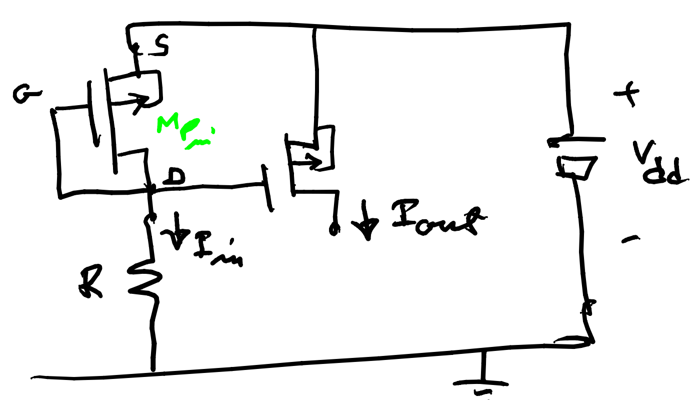
$I_{out} = \frac{KP}{2} \cdot \left(\frac{W}{L}\right)_{out} (V_{GS} - VTO)^2$

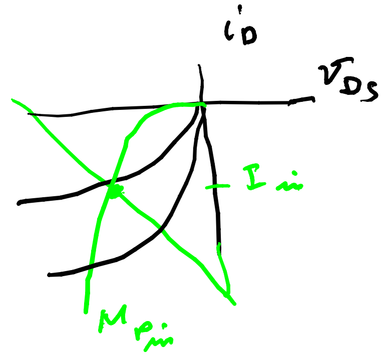
$= \frac{KP}{2}\left(\frac{W}{L}\right)_{out} \left(\frac{I_{in}}{\frac{KP}{2}(W/L)_{in}} \right) = \frac{\left(\frac{W}{L}\right)_{out}}{\left(\frac{W}{L}\right)_{in}} \cdot I_{in}$ if M_{out} in saturation

here M_{out} doesn't load M_{in} (at DC)

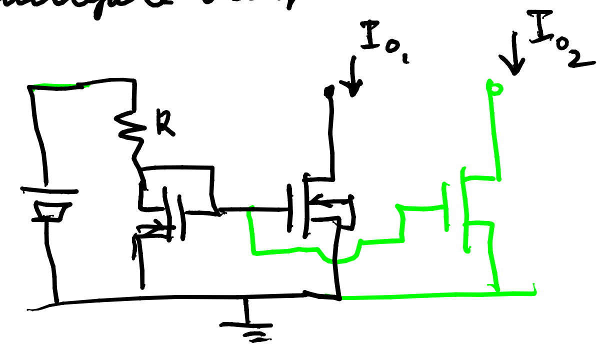
while for BJT, Q_{out} loads Q_{in}







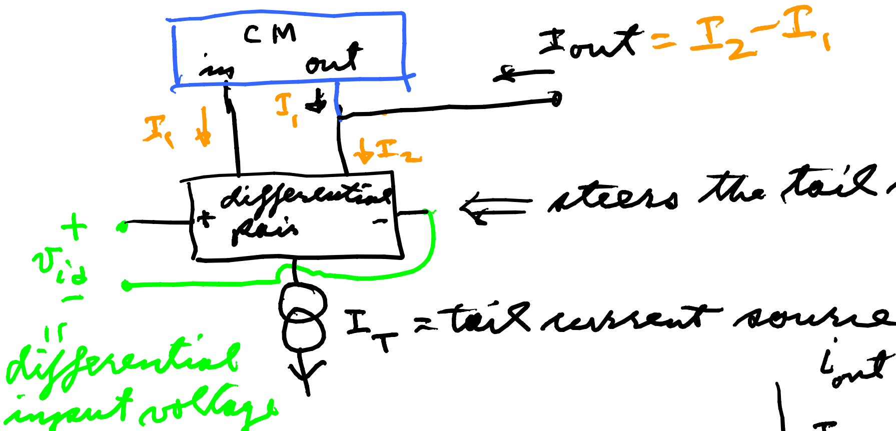
For multiple output

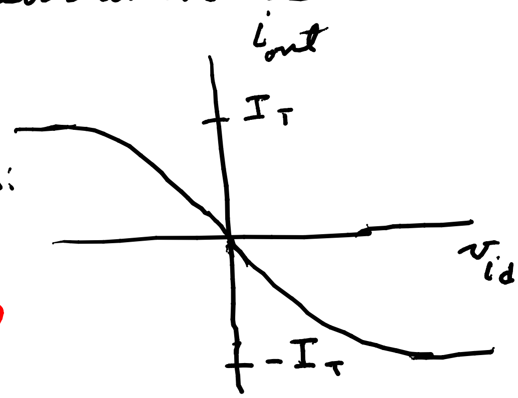


Use these in OTA's ; OTA = operational transconductance amplifier

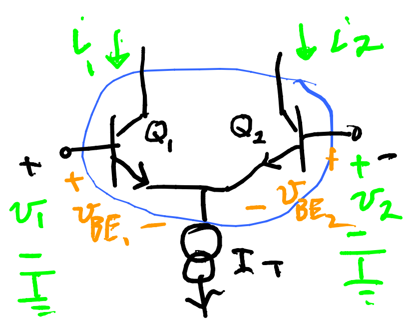
= VCCS

use differential pairs
current & current mirrors





For the BJT differential pair:



; $v_{id} = v_1 - v_2$

see p. 710

by KCL: ignore base current

$$i_1 + i_2 - I_T = 0$$

for an OTA: $i_o = i_2 - i_1$

(1) $\Rightarrow I_T = i_1 + i_2 = \frac{i_1 + i_2}{\alpha}$ as emitter

(2) $i_o = i_2 - i_1$

desire i_o vs v_{id} $\Rightarrow$ $i_o = -\alpha I_T \tanh(v_{id}/2V_T)$ end result

$$g_m = \left.\frac{d i_o}{d v_{id}}\right|_{v_{id}=0} = \text{small signal gain}$$

add (1)+(2): $2 i_2 = I_T + i_o$

subtract (1)−(2) $2 i_1 = I_T - i_o$

for $Q_1 \Rightarrow i_{E_1} = I_S e^{v_{BE_1}/V_T}$; $i_{E_2} = I_S e^{v_{BE_2}/V_T}$ (3), (4)

$v_1 - v_2 + v_{BE_2} - v_{BE_1} = 0$ by KVL

$v_{id} = v_{BE_1} - v_{BE_2} \Rightarrow v_{BE_2} = v_{BE_1} - v_{id}$ (5)

$i_{C_1} = \alpha i_{E_1} = \alpha I_S e^{v_{BE_1}/V_T}$, $i_{C_2} = \alpha i_{E_2} = \alpha I_S e^{(v_{BE_1} - v_{id})/V_T}$

$i_{C_1} = i_1$, $i_{C_2} = i_2$

ratio
$$\frac{i_o}{I_T} = \frac{i_2 - i_1}{i_2 + i_1} = \frac{\alpha I_S e^{\frac{v_{BE_1}}{V_T}} \cdot e^{-v_{id}/V_T} - \alpha I_S e^{v_{BE_1}/V_T}}{\alpha I_S e^{\frac{v_{BE_1}}{V_T}} \cdot e^{-v_{id}/V_T} + \alpha I_S e^{v_{BE_1}/V_T}}$$

$$= \frac{e^{-v_{id}/V_T} - 1}{e^{-v_{id}/V_T} + 1} = -\frac{e^{-v_{id}/2V_T}\left(e^{v_{id}/2V_T} - e^{-v_{id}/2V_T}\right)}{e^{-v_{id}/2V_T}\left(e^{v_{id}/2V_T} + e^{-v_{id}/2V_T}\right)}$$

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

$\Rightarrow$ $i_o = -I_T \tanh(v_{id}/2V_T)$ as predicted but off by α

$\Rightarrow \frac{1}{1/\alpha} \Rightarrow i_o = -\alpha I_T \tanh(v_{id}/2V_T)$

as have to supply base current