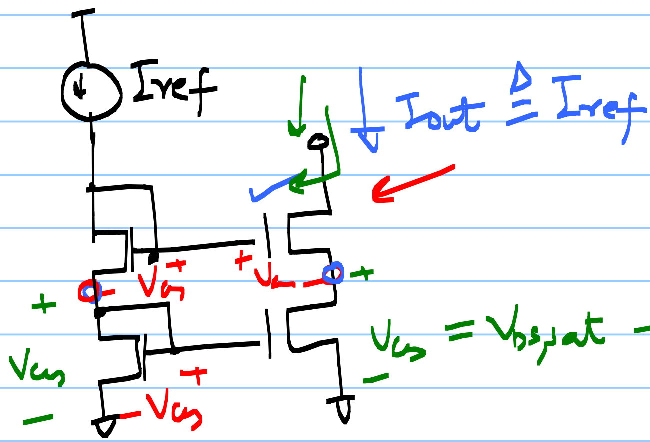
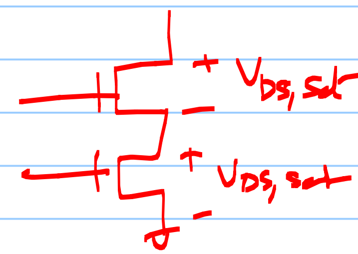
ECE 5411 — Lecture 10

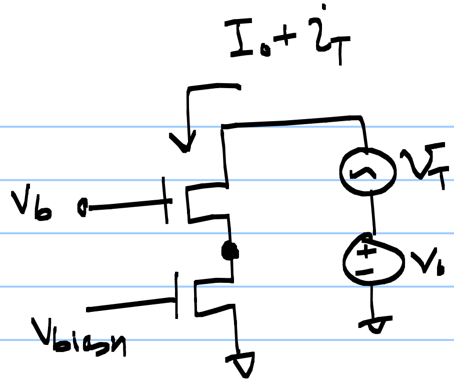
Note Title 2/19/2011

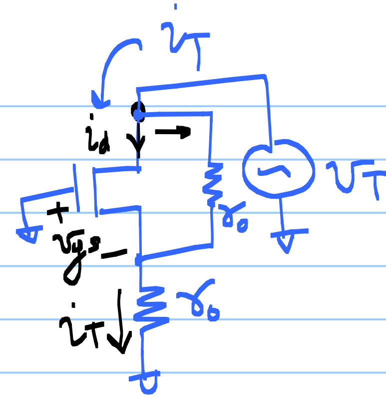


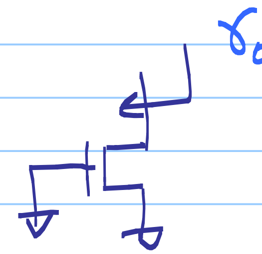
$V_{GS} = V_{DS,sat} + V_{THN}$

$$V_o \geq V_{GS} + V_{DS,sat}$$
$$= 2V_{DS,sat} + \boxed{V_{THN}}$$









KVL: $v_{gs} + i_T r_o = 0 \Rightarrow v_{gs} = -i_T r_o \longrightarrow (1)$

$$R_o = \frac{v_T}{i_T}$$

KCL: $i_T - g_m v_{gs} - \dfrac{(v_T - (-v_{gs}))}{r_o} = 0 \longrightarrow (2)$

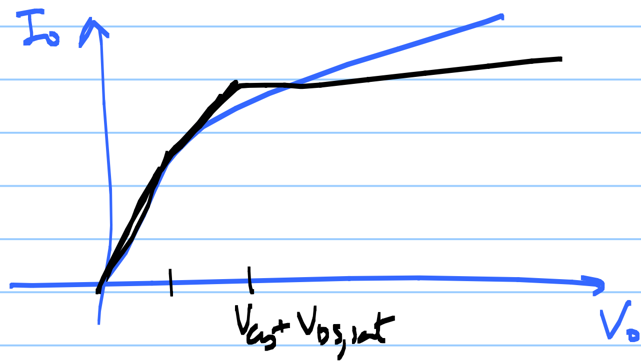
Eliminate v_{gs}: $v_{gs} = -i_T r_o$

$$i_T + g_m r_o i_T - \frac{v_T}{r_o} + i_T = 0$$

$$\frac{v_T}{i_T} = (2 + g_m r_o) r_o = 2r_o + g_m r_o^2$$ if $g_m r_o >> 1$

$$\simeq \boxed{g_m r_o^2} \leftarrow$$

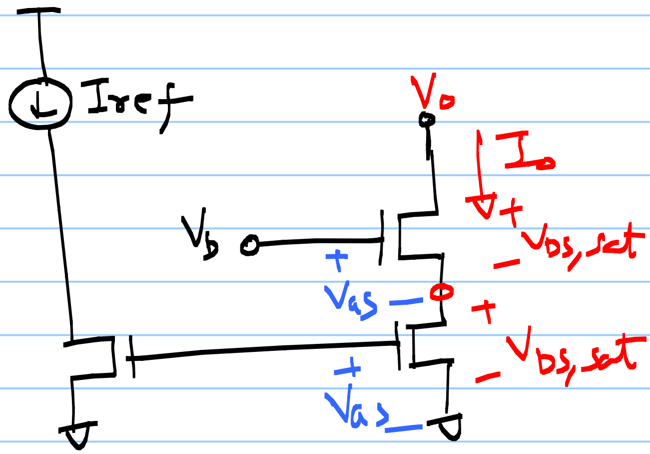
$$= r_o \cdot (g_m r_o)$$



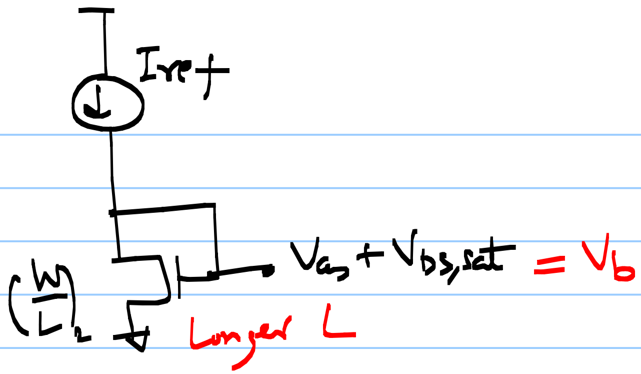
R_o is enhanced by $g_m r_o >> 1$

Wide-Swing Cascode Current Mirrors

$$V_o \geq 2V_{DS,sat}$$



$$V_b = V_{GS} + V_{DS,sat}$$
$$= 2V_{DS,sat} + V_{THN}$$



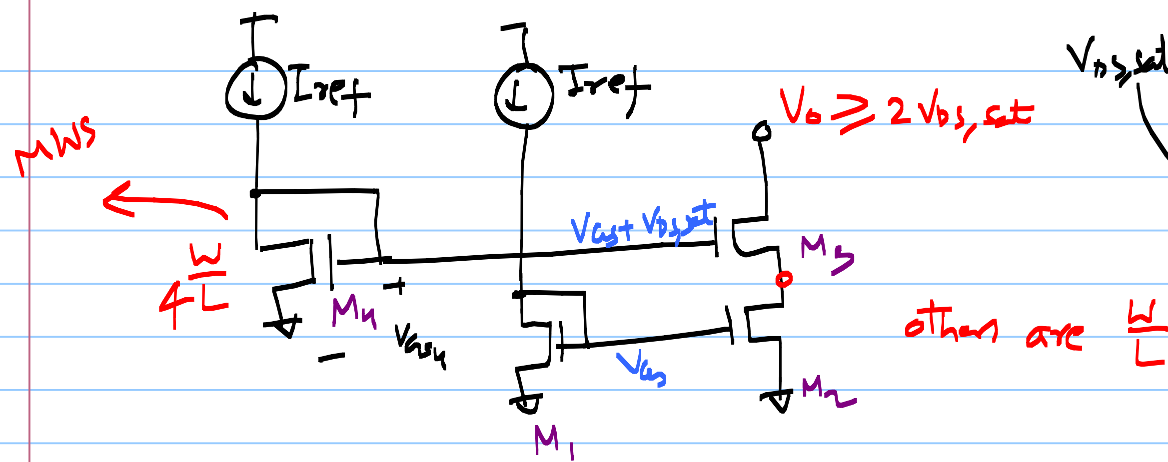
I_D is constant

$$V_{GS} = \sqrt{\frac{2 I_D}{KP_n (W/L)}} + V_{THN}$$

for higher V_{GS} for same current

$\left(\frac{W}{L}\right) \downarrow$

$\Rightarrow L \uparrow$



$V_{DS,sat} + \cancel{V_{THN}} = V_{GS} = \sqrt{\frac{2I_n}{\beta}} + \cancel{V_{THN}}$

$\beta = kP_n \frac{W}{L}$

Find β_4

$V_{GS4} = 2V_{DS,sat} + \cancel{V_{THN}} = \sqrt{\frac{2I_{ref}}{\beta_4}} + \cancel{V_{THN}}$

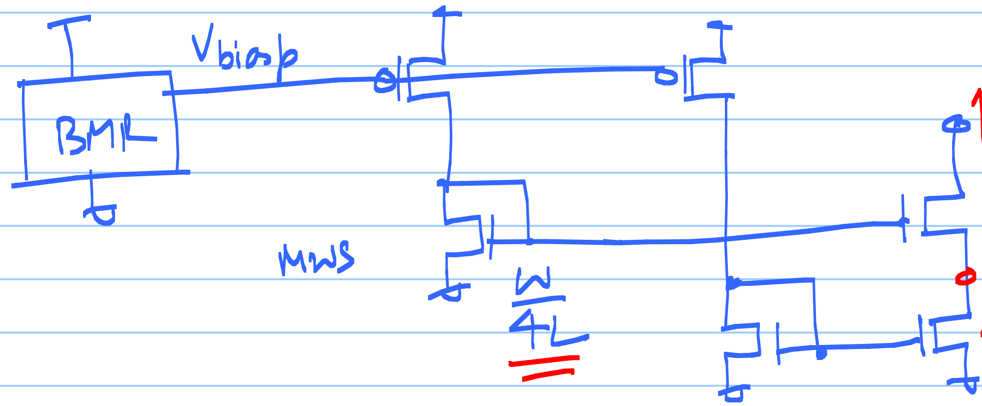
$\Rightarrow \quad 2\sqrt{\frac{\cancel{2I_{ref}}}{\beta}} = \sqrt{\frac{\cancel{2I_{ref}}}{\beta_4}}$

$\Rightarrow \quad 2\sqrt{\beta_4} = \sqrt{\beta}$

$$\Rightarrow \boxed{\beta_4 = \frac{\beta}{4}}$$

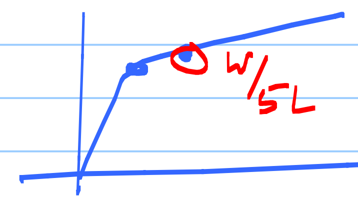
$$\Rightarrow \boxed{\left(\frac{W}{L}\right)_4 = \frac{W}{4L}}$$

Long-L MOS device gives larger V_{GS_4} for the same current.



Wide-Swing Cascode Current mirror

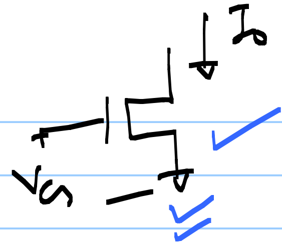
right on the verge of triode

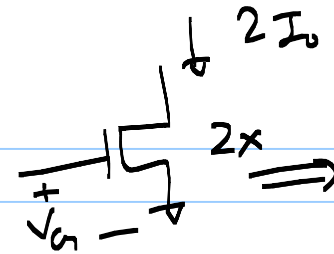


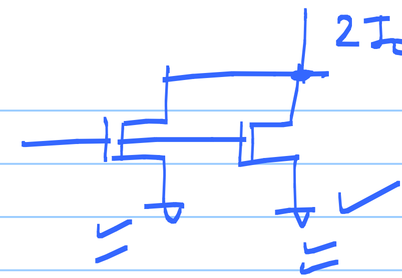
$\frac{W}{5L}$ is better

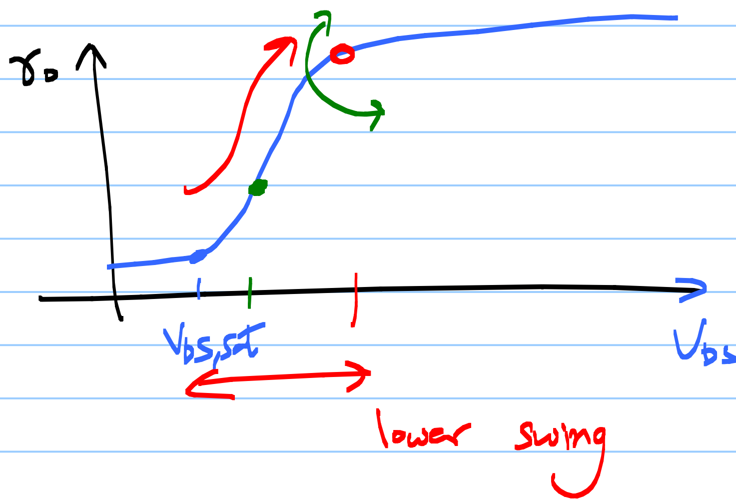
↳ slightly lower swing

* Matching







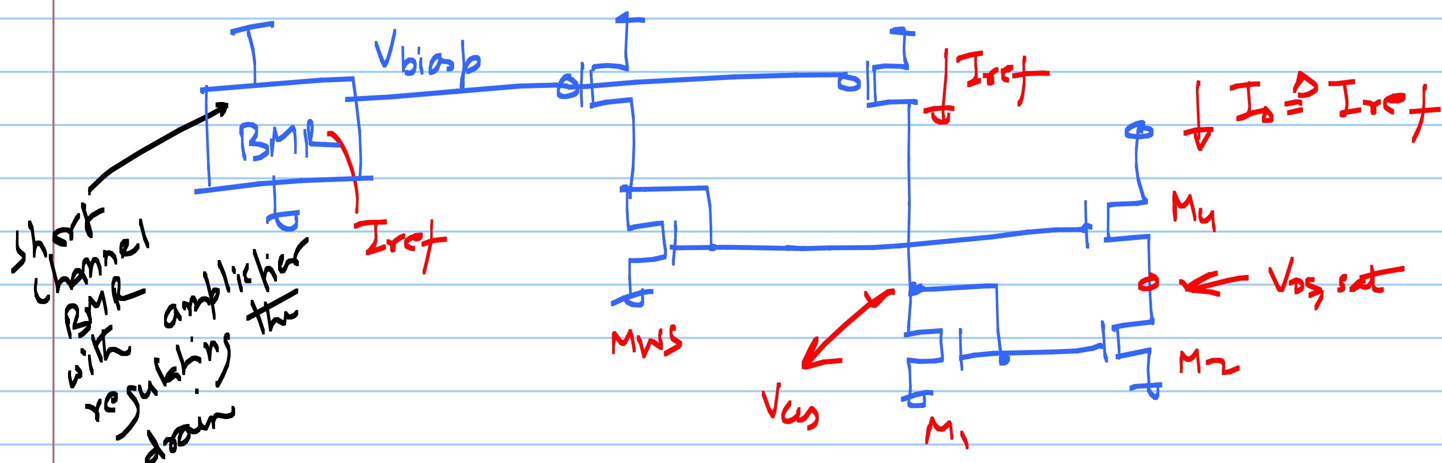


$$\left(\frac{W}{L}\right)_{MWS} = \frac{W}{25L}$$ for 50nm

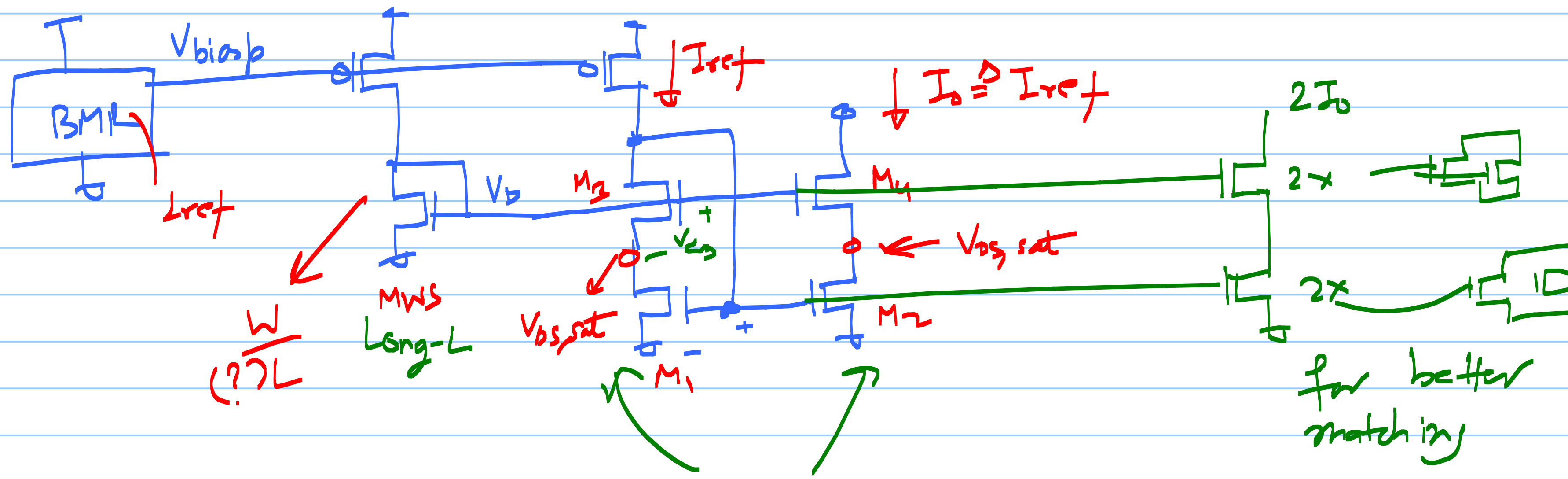
* Bias the bottom device deeper into saturation

⇒ Larger 'L' in MWS device.

Short-channel Cascode Current Mirrors

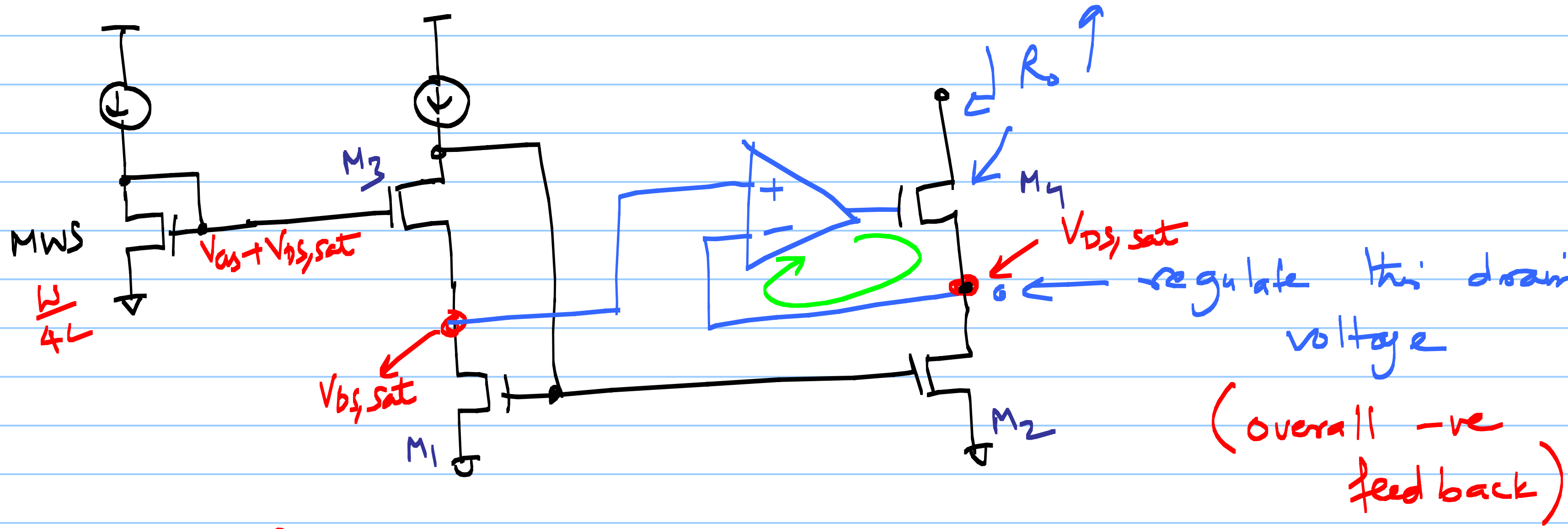


× V_{DS} of M_1 & M_2 are not the same.



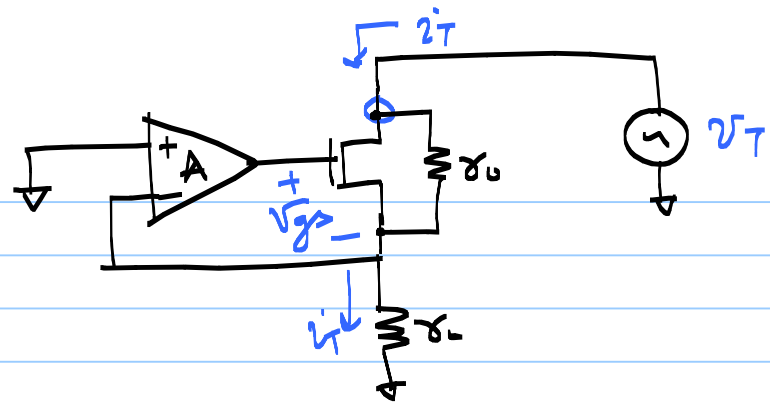
VDS of M1 & M2 are matched.

Regulated Drain Current Mirror :



If $A \to \infty$,

$\Rightarrow V_{D2} = V_{D1} \Rightarrow R_o \to \infty$



$$(0 - i_T r_o)A = i_T r_o + v_{gs}$$

$$\Rightarrow \quad -i_T r_o (A+1) = v_{gs} \longrightarrow (1)$$

KCL:

$$i_T - g_m v_{gs} - \frac{(v_T - i_T r_o)}{r_o} = 0$$

$$\Rightarrow \quad i_T + g_m r_o (A+1)\, i_T - \frac{v_T}{r_o} + i_T = 0$$

$$\Rightarrow \quad \frac{v_T}{r_o} = i_T\left(2 + g_m r_o (A+1)\right)$$

$$\Rightarrow \quad R_o = \frac{v_T}{i_T} = \left(2 + g_m r_o (A+1)\right) r_o$$

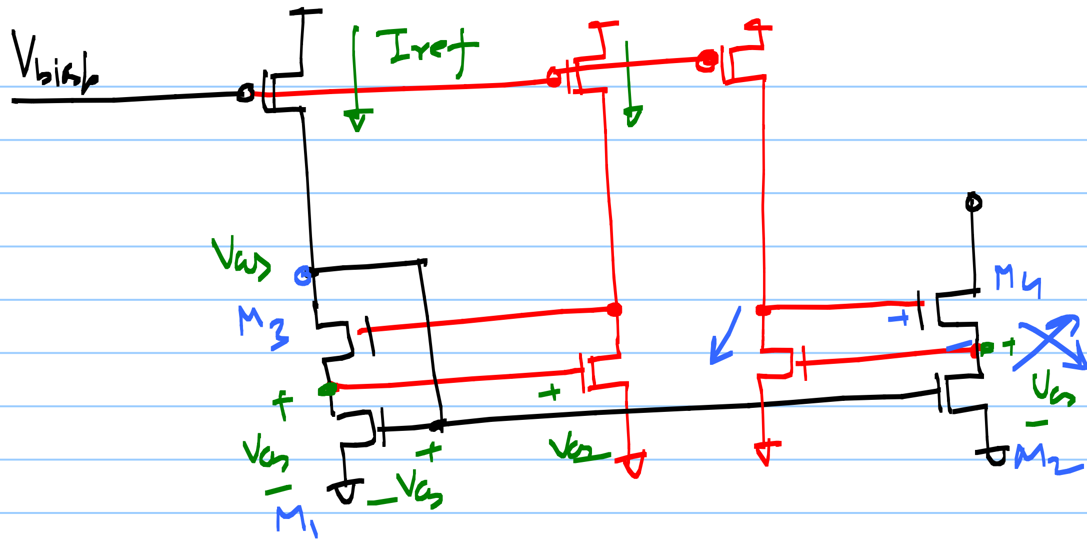
$$= 2r_o + g_m r_o^2 (A+1)$$

$A >> 1$

$g_m r_o >> 1$

$$\simeq g_m r_o^2 A$$

$\Rightarrow$ output resistance is enhanced by the amplifier gain.



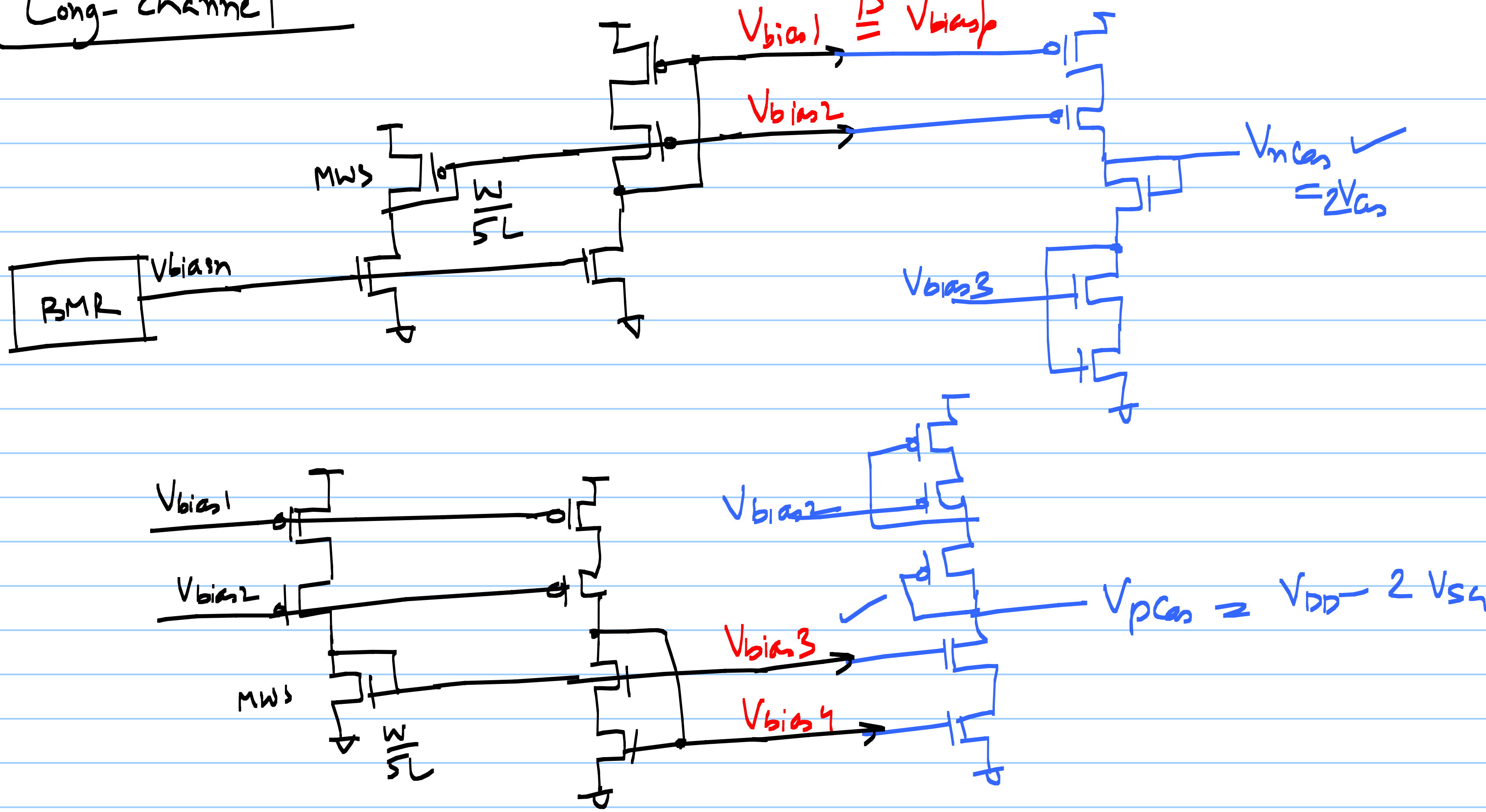
* Not a wide-swing current mirror

"-ve feedback"

$$R_o = (g_m r_o^2)\, A \quad A = \frac{g_m r_o}{2}$$

$$= \frac{g_m^2 r_o^3}{2}$$

Long-channel

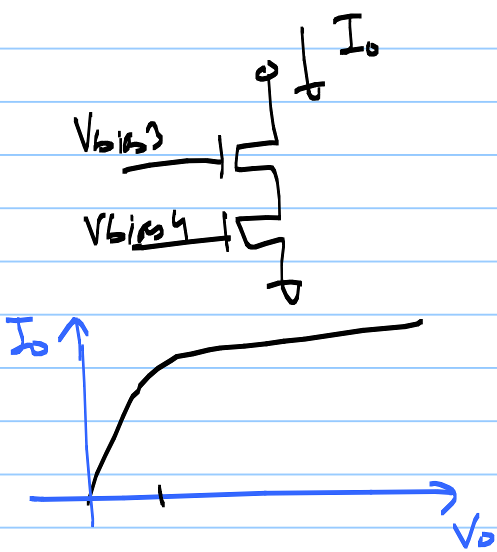


For short-channel

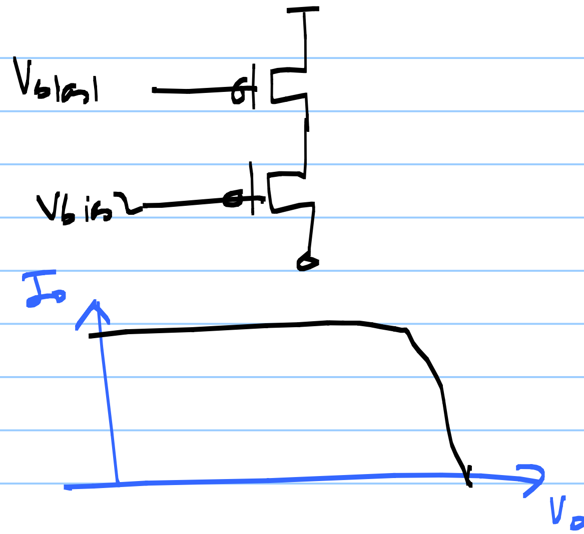
↳ use drain regulated BMR

↳ Adjust $\frac{W}{L}$ of the MOS devices.

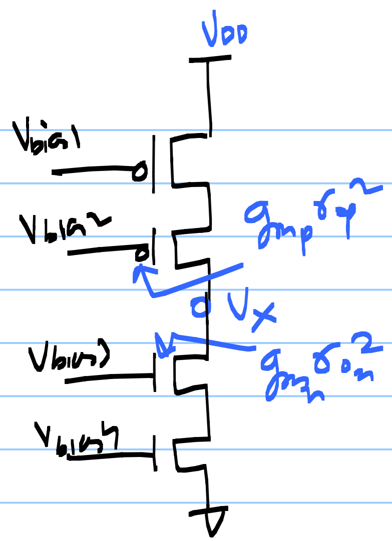
Ex. 50n → $\frac{W}{25L}$

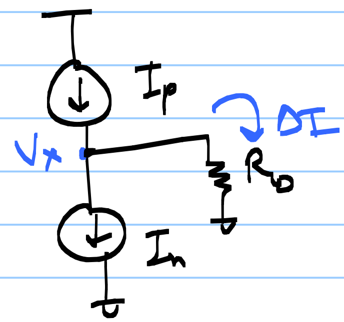


I_o
Vbias3
Vbias4
I_o
V_o



Vbias1
Vbias2
I_o
V_o





$\Delta I = I_p - I_n$

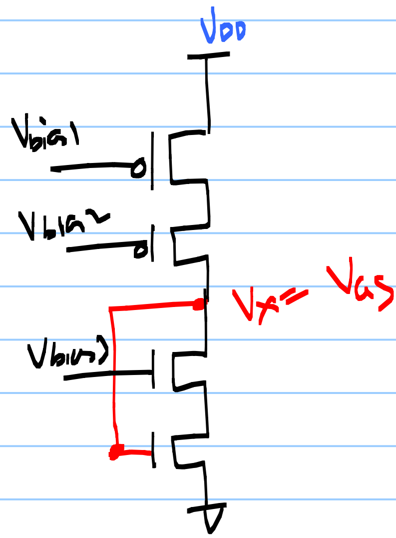
① $I_p > I_n$

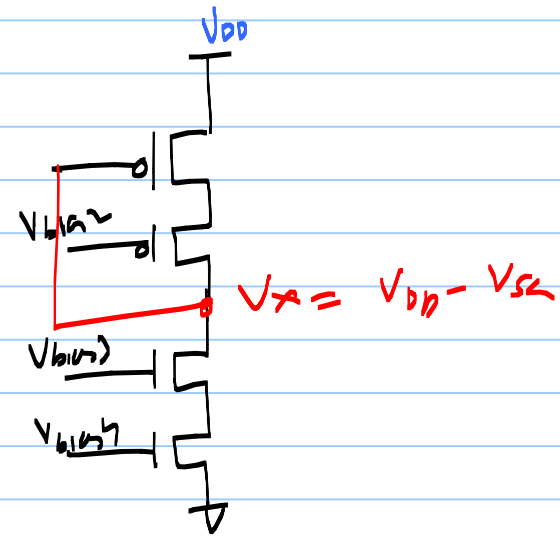
* V_x keeps on increasing till I_p shuts down

② $I_p < I_n$

* V_x hits the ground rail

* Cannot have two "independent" current sources fighting each other.


VDD
Vbias1
Vbias2
Vx = VGS
Vbias3


VDD
Vbias2
Vx = VDD - VSG
Vbias3
Vbias4

Floating Current Source