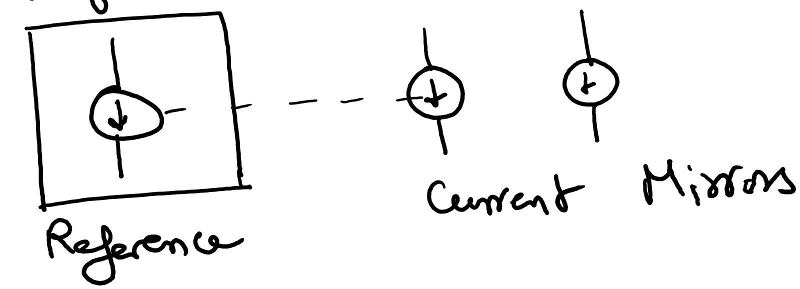
ECE 511 - Lecture 6

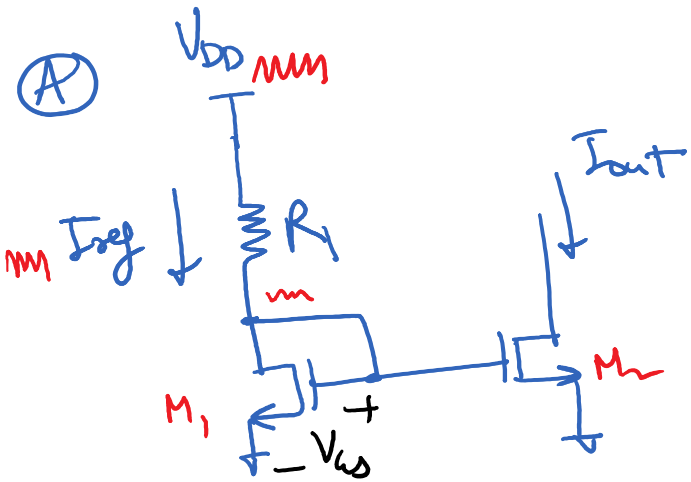
Tuesday, September 11, 2018 11:00 AM

I_{ref}



$\lambda = 0$

$\beta_n = k'_n \frac{W}{L}$



$$I_{ref} = \frac{V_{DD} - V_{GS}}{R_1} = \frac{\beta_n}{2}(V_{GS} - V_{THN})^2$$

$$I_{ref} = f(V_{DD})$$

$$\Delta I_{out} = \frac{\Delta V_{DD}}{R_1 + \frac{1}{g_{m1}}} \cdot \frac{(W/L)_2}{(W/L)_1}$$

$$V_{GS} = \sqrt{\frac{2I_D}{\beta}} + V_{THN}$$

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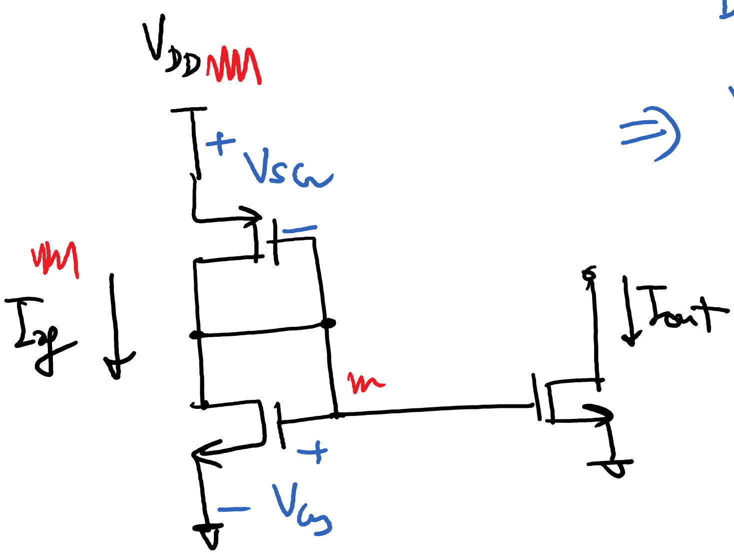
(B)



$$V_{DD} = V_{SG} + V_{GS}$$

$$\Rightarrow V_{DD} = \sqrt{\frac{2I_{ref}}{\beta_p}} + V_{THP} + \sqrt{\frac{2I_{ref}}{\beta_n}} + V_{THN}$$

$$\left(V_{DD} - V_{THN} - |V_{THP}|\right)^2 = I_{ref}\left(\sqrt{\frac{2}{\beta_p}} + \sqrt{\frac{2}{\beta_n}}\right)^2$$

$$I_{ref} = \frac{\left(V_{DD} - V_{THN} - V_{THP}\right)^2}{\left(\sqrt{\frac{2}{\beta_p}} + \sqrt{\frac{2}{\beta_n}}\right)^2}$$

$V_{DD} < V_{THN} + V_{THP}$

$I_{ref} = 0$

Trivial Case

$$\Delta I_{ref} = \frac{\Delta V_{DD}}{1/g_{mn} + 1/g_{mp}}$$

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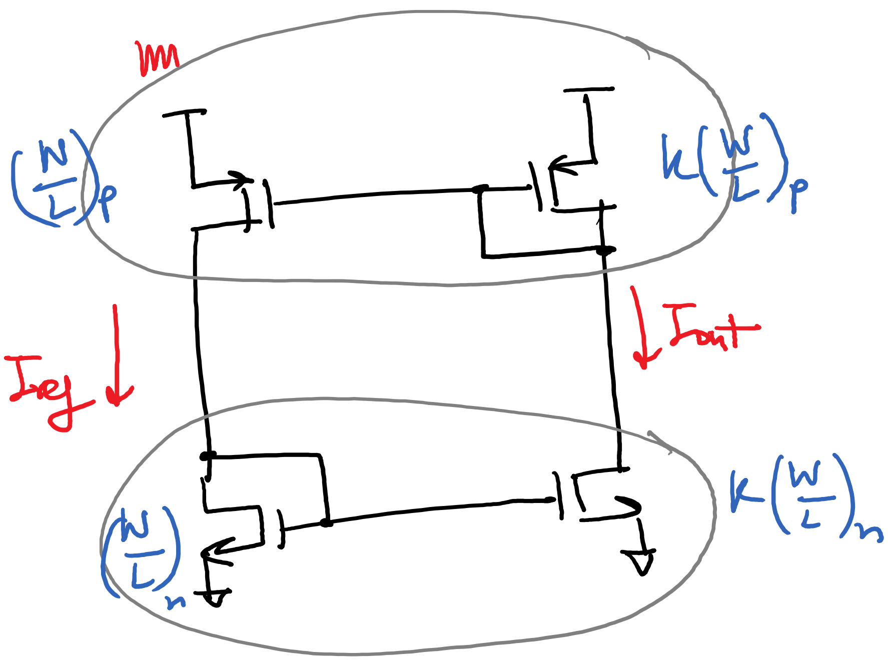
In order to get rid of V_{DD} sensitivity, the circuit must bias itself.

↳ I_{ref} must be derived from I_{out}



top mirror copies I_{out} to I_{ref}

bottom mirror copies I_{ref} to I_{out}!

$I_{out} = kI_{ref}$ (assuming $\lambda = 0$)

I_{ref} & I_{out} are independent of V_{DD}.

How do we set the values of I_{ref} & I_{out}?

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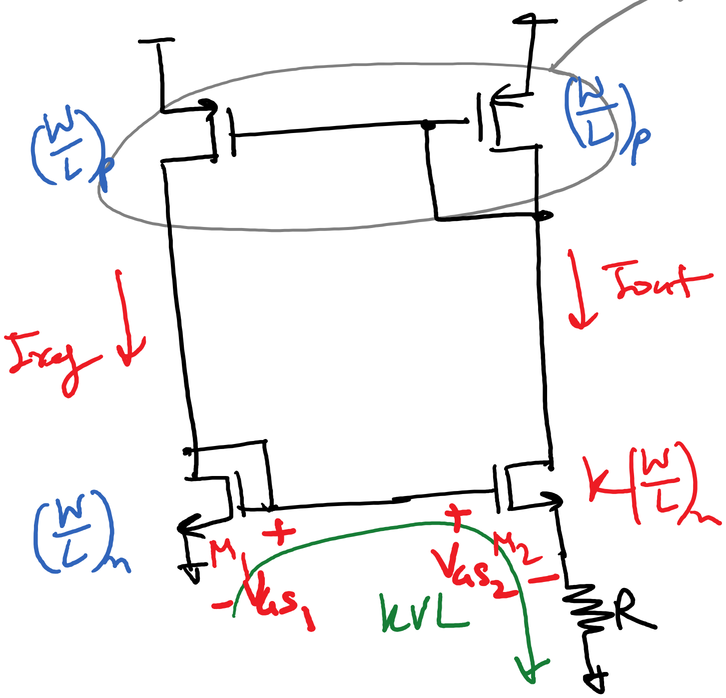
$I_{out} = I_{ref}$



$$V_{GS_1} = V_{GS_2} + I_{out} R$$

$$\sqrt{\frac{2 I_{out}}{KP_n \left(W/L\right)_1}} + \cancel{V_{THN_1}} = \sqrt{\frac{2 I_{out}}{KP_n \left(W/L\right)_1 K}} + \cancel{V_{THN_2}} + I_{out} R$$

ignoring body-effect: $V_{THN_1} = V_{THN_2}$

$$\sqrt{\frac{2 I_{out}}{KP_n \left(\frac{W}{L}\right)}} \left(1 - \frac{1}{\sqrt{K}}\right) = I_{out} \cdot R$$

$$\boxed{I_{out} = 0, \quad \frac{2}{KP_n \left(\frac{W}{L}\right) R^2} \cdot \left(1 - \frac{1}{\sqrt{K}}\right)^2 = I_{ref}}$$

Independent of supply voltage

Beta Multiplier Reference (BMR)

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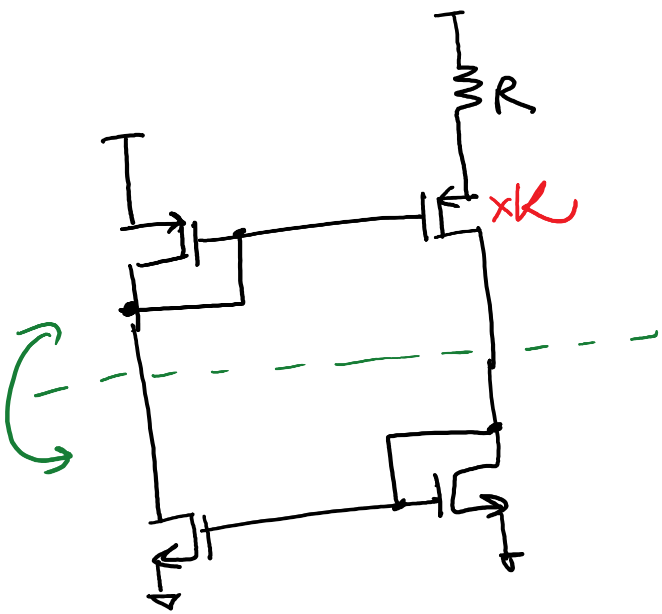
↳ independent of V_{DD} ($\lambda = 0$)

not independent of Temp.



Transconductance of M_1: $\sqrt{2\beta I_{ref}}$

$$g_{m_1} = \sqrt{2\beta I_{ref}}$$

$$= \sqrt{2\, \cancel{kP_n\left(\frac{W}{L}\right)_1} \cdot \frac{2}{\cancel{kP_n\left(\frac{W}{L}\right)_1}} \cdot \frac{1}{R^2}\left(1-\frac{1}{\sqrt{K}}\right)^2}$$

$$\Rightarrow g_m = \frac{2}{R}\left(1-\frac{1}{\sqrt{K}}\right)$$

indep of V_{DD} & V_{THN} etc

varies with temp

$\Rightarrow$ Constant-g_m biasing circuit

for $K=4$, $g_m = \frac{1}{R}$

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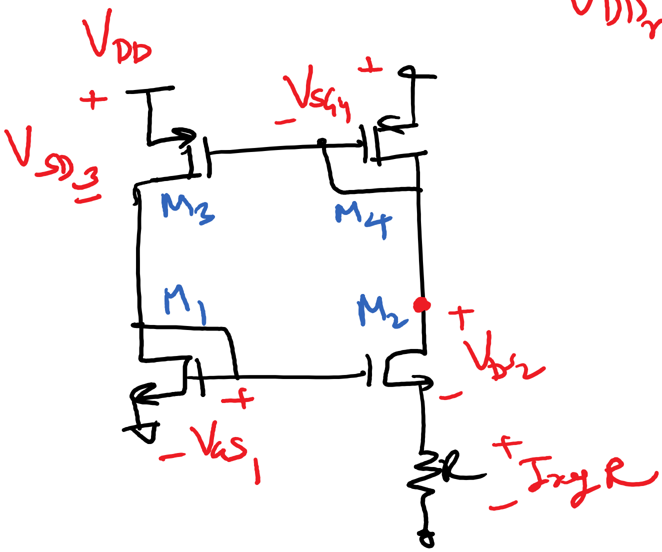
$$V_{DD_{min}} = \max\left\{ V_{GS_1} + V_{SD_3,sat},\ V_{SG_4} + V_{DS,sat_2} + I_{xy} \cdot R \right\}$$



Start-up problem

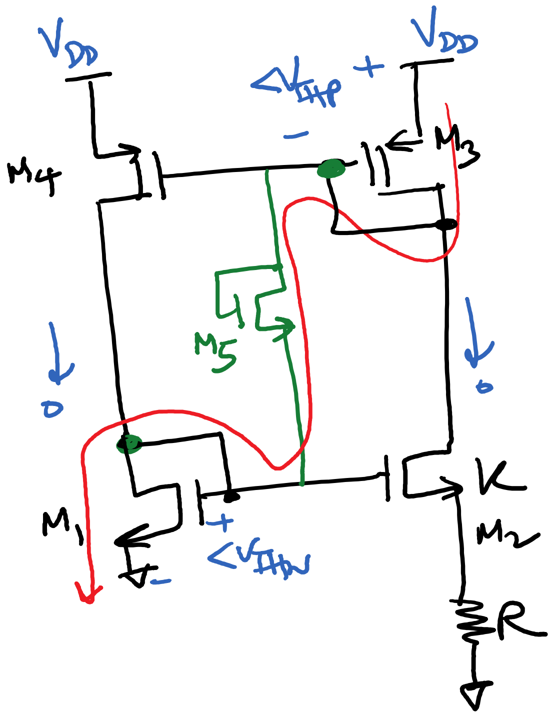
If all transistors carry zero current when V_{DD} is turned on

↳ they may remain off indefinitely.

∵ $I_{out} = 0$ is also an admissible solution.

↳ degenerate bias condition ($I_{ref} = I_{out} = 0$)

↳ need to force the devices to turn-on.



M_5 is providing current path from M_3 to M_1 so that they snap to the desired solution for I_{ref}.

× But M_5 should be off during normal operation

for M_5 to turn-off,

$V_{THN_1} + V_{THN_5} + V_{THN_3} < V_{DD}$ to turn on M_5 → ①

$V_{GS_1} + V_{THN_5} + V_{SG_3} > V_{DD}$ to turn off M_5 → ②

$V_{DD} - (V_{GS_1} + V_{SG_3}) < V_{THN_5}$

Not very robust idea.

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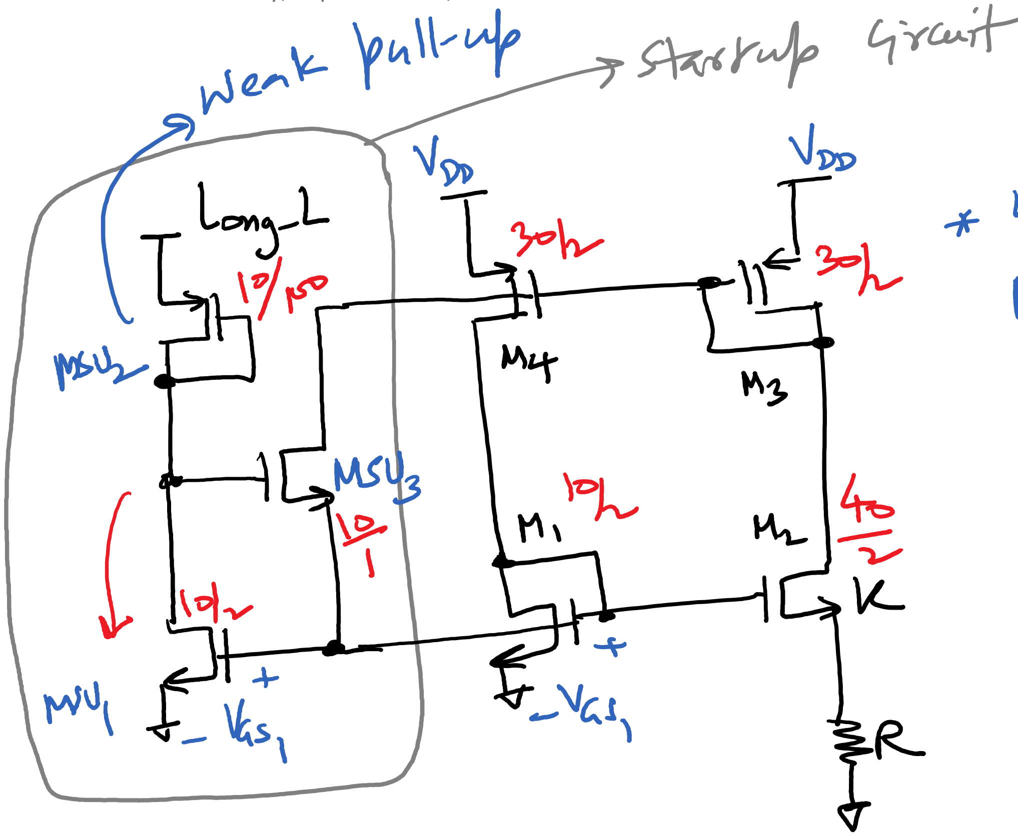

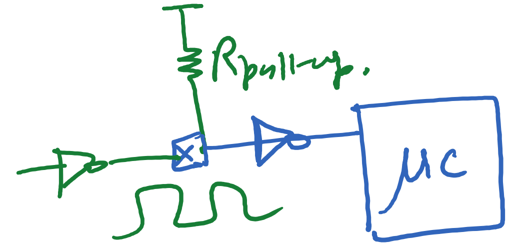

* when BMR is in zero-current state MSU1 is off

MSU2 turns on and leaks current into M1 and M3

↳ causes M1 & M3 turn on & the BMR snaps to the desired state

⇒ when M1 is ON ⇒ VGS1

M1 mirrors MSU1

⇒ MSU1 is ON

↳ MSU1 pulls down gate of MSU3

↳ MSU3 shuts off

→ The SUT is turned off in

normal state

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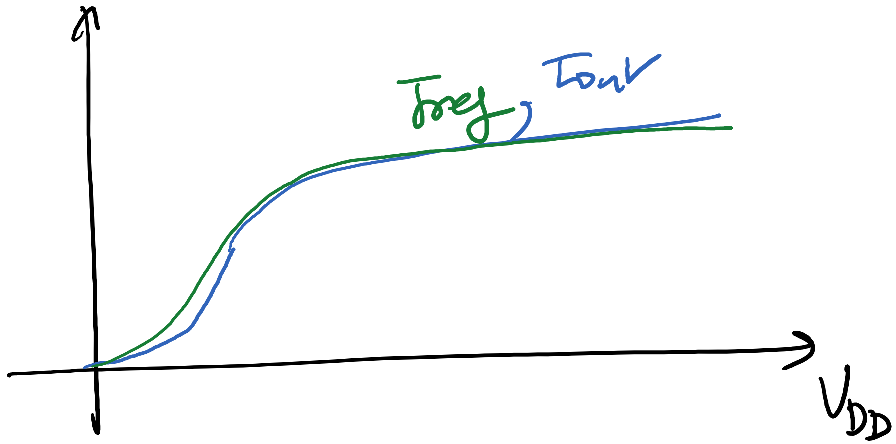
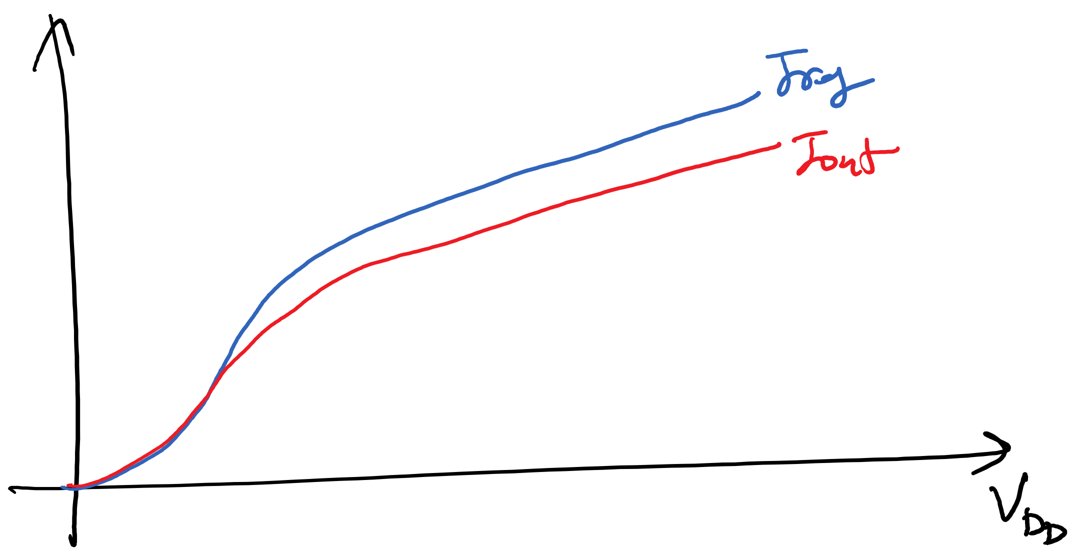
In long-L process:



Short-channel process:



Not very accurate and supply independent due to CLM.